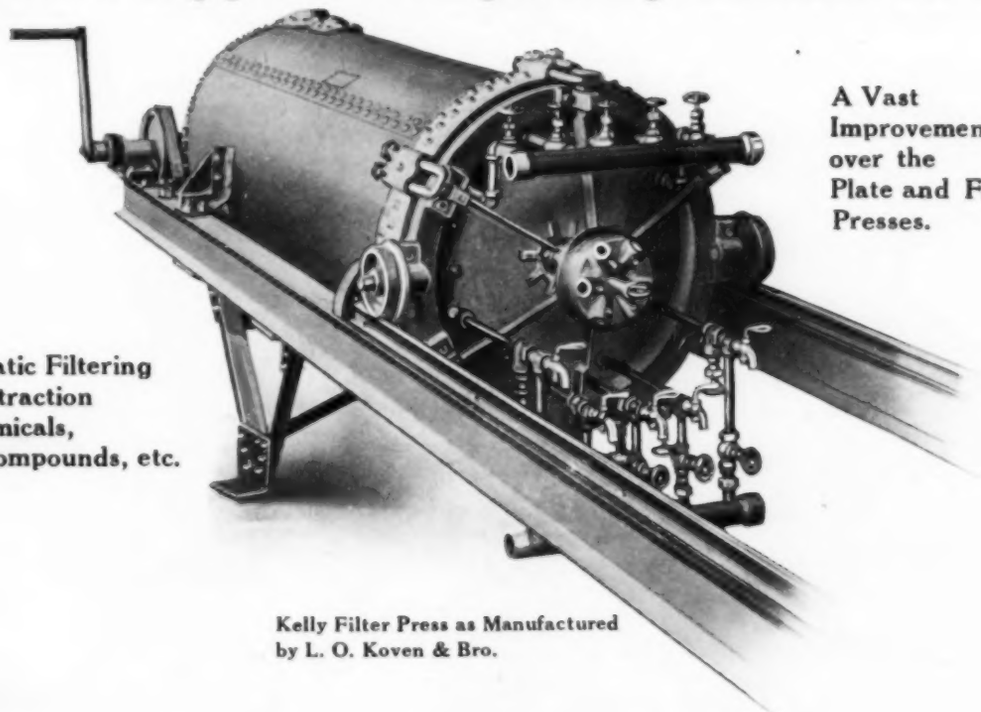
Metallurgical and Chemical Engineering

An Incorporation of

Electrochemical and Metallurgical Industry—Iron and Steel Magazine

Vol. XI. No. 10 New York, October, 1913. 25 cts. per Copy. $2.00 per Year to U. S. and Mexico. $2.50 per Year to other Countries.

Use Our Facilities To Improve Yours
We Make Apparatus Specially Suited To Needs



A Vast Improvement over the Plate and Frame Presses.

Automatic Filtering and Extraction of Chemicals, Oils, Compounds, etc.

Kelly Filter Press as Manufactured by L. O. Koven & Bro.

If { You Need Apparatus to Sell / You Need Apparatus to Use } We Can Make It

Consult Us When You Contemplate Buying Apparatus

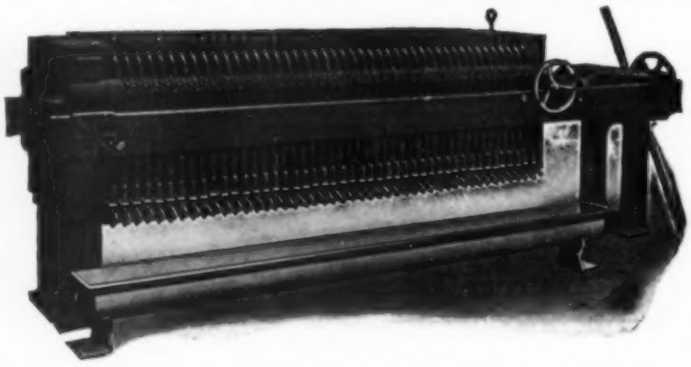
TANKS *GALVANIZERS*

L. O. KOVEN & BRO.

50 Cliff Street, New York Works at Jersey City, New Jersey

Alphabetical Index and Classified Directory, pages 102, 103, 104, 105

We build more FILTER PRESSES than any other Manufacturer



because Shriver's Filter Presses embody such improvements as THE WIDE JOINT SURFACES of the plates and frames, greatly lengthening the life of the filter cloths. Presses designed and constructed for any class of industrial filtration. Small presses for laboratory work.

T. SHRIVER & CO.

Office and Works

808 Hamilton St. HARRISON, N. J.

If You Want to Produce Castings of Better Quality Use

Goldschmidt "Carbon-Free" Ferro-Titanium

This alloy contains 25% Titanium, 6% Aluminum, and is largely used in the manufacture of steel and iron to improve the material. On account of its purity, only a very small addition is necessary, and therefore the increased cost is very low—about 25 to 50 cents per ton. In practically every case we have been able to eliminate the use of metallic Aluminum, which is an important feature. It is used to thoroughly deoxidize and cleanse the metal, which is more efficiently done by the use of this alloy than in any other way. In iron and steel castings, for instance, the metal is much more solid and closer grained, more free from blow-holes, sand holes, etc., and the castings are therefore more easily machined and more uniform in quality. It is largely used for cast steel and sand cast iron rolls, gears, cylinders and pressure parts, also in sheets, plates, forging steel, rails, high-grade wire work and tool steels.

We will be pleased to enter your sample order for carbon-free ferro-titanium, and believe that you will be more than pleased with results obtained.

Prices, analysis, etc., quoted on inquiry, also other metals and alloys for iron, steel, brass, composition, German silver, nickel and Monel metal.

Our new pamphlet No. 2041 on carbon-free metals and alloys will be sent upon request.

Test Bar Twisted Cold from Steel Treated with Carbon-Free Ferro-Titanium

GOLDSCHMIDT THERMIT CO.

WILLIAM C. CUNTZ, General Manager

90 WEST STREET, NEW YORK

329-333 Folsom St., San Francisco 103 Richmond St., W., Toronto, Ont.

7300 So. Chicago Ave., Chicago.

METALLURGICAL & CHEMICAL ENGINEERING

ISSUE OF OCTOBER, 1913

Colorado Meeting of the American Electrochemical Society 569

A full account of the proceedings of the meeting held in September in Denver, Boulder, and Golden, with a final session on Pike's Peak and an excursion to Cripple Creek, together with detailed abstracts of all the papers presented and of the discussions which followed.

Continuity Versus Atomism—The Limitations of the Scope of Physics and Chemistry. By Sir Oliver Lodge 545

His presidential address before the British Association for the Advancement of Science, in which Sir Oliver Lodge takes a strong stand in favor of continuity versus atomism and also points out forcibly the limitations of the scope of physics and chemistry.

Quantitative Spectrum Analysis. By G. A. Shook 552

A second article of his illustrated serial on this subject. In the present installment the author describes various types of spectrophotometers and discusses their relative advantages and disadvantages.

Mill Physiology. By Stephen L. Goodale 566

While there exists extensive literature on what may be called mill anatomy, the author points out that mill physiology—a study of the mill in operation in its parts and as a unit—is usually neglected. The author emphasizes the importance of this viewpoint in teaching metallurgy.

Induction Furnace Notes. By Joh. Harden 559

Notes on a recent electric steel refining installation in an English crucible steel works, with details of design and cost of operation.

Electric Furnaces, Their Design, Characteristics, and Commercial Applications. By W. McA. Johnson and George N. Sieger 563

The second article of their illustrated serial in which they discuss specific design and important details, especially electrodes.

Quantitative Determination of the Precious Metals Gold, Silver and Platinum. By Trenkner 567

A description of a new method of analysis which permits a much higher accuracy than was formerly obtainable.

EDITORIAL:
- Colorado Meeting of the American Electrochemical Society 535
- Handling Slime at Anaconda 536
- The Trend of Tube Milling 536
- Steel Under the New Tariff 537

READERS' VIEWS AND COMMENTS:
- Continuous Counter-Current Decantation. By John V. N. Dorr 538
- Hydrometallurgy—Joys of Its Theory. Woes of Its Practice. By Warren F. Bleecker 538
- New York Section of the American Electrochemical Society 539
- Iron and Steel Meeting of American Institute of Mining Engineers 540
- Chicago Meeting of American Institute of Metals 540
- American Institute of Chemical Engineers 540
- New York Section of the American Chemical Society 540
- Western Metallurgical Field 540
- Iron and Steel Market 542
- The Non-Ferrous Metal Market 543
- A Study of the Oxidation of Coal and of the Process of Combustion. By Horace C. Porter 543
- Corrosion Report Before the British Institute of Metals 544
- Winona Stamp Mill. By R. B. Seeber 549
- Determination of Oxygen in Copper and Brass 558
- Annealing of Gold 558
- Improvements in Smelting at the Consolidated Company's Works, Trail, B. C. By E. C. Jacobs 562
- Volume Changes in Alloys 568
- Phosphorus in Copper—Aluminum Alloys 568
- Some Aspects of Heat Flow. By E. F. Northrup 572
- Flow of Heat Through Furnace Walls. By I. Langmuir, E. Q. Adams and G. S. Meikle 574
- Heat Resistivity of Graphite and Carbon. By Jos. W. Richards 575
- Electrolysis of Cyanide Solution. By E. F. Kern 575
- Electrolysis of Aqueous Solutions of Alkaline Cyanides. By G. H. Clevenger and M. L. Hall 577
- Possible Applications of the Electric Furnace to Western Metallurgy. By Dorsey A. Lyon and R. M. Keeney 577
- Progress in Electrostatic Ore Dressing. By Frank S. MacGregor 581
- Transformation of Radiant into Chemical Energy. By S. C. Lind 582
- The Art of Electric Zinc Smelting. By W. McA. Johnson 582
- The Electric Zinc Furnace. By P. A. Peterson 583
- Electric Smelting of Chromium, Tungsten, Molybdenum and Vanadium Ores. By Robert M. Keeney 585
- The Carnotite Industry. By Siegfried Fischer 586
- Base-Metal Thermocouples. By O. L. Kowalke 588
- Osmium-Platinum, a New Alloy. By F. Zimmermann 590
- Effect of Light on Decomposition Voltage. By Alan Leighton 590
- Rapid Refining of Copper with a Rotating Cathode. By C. W. Bennett and C. O. Brown 590
- Simultaneous Determination of Copper and Lead with the Rotating Anode. By Arthur J. White 590
- Solid Thick Deposits of Lead from Lead Acetate Solution. By Frank C. Mathers 591
- Synopsis of Recent Chemical and Metallurgical Literature 591
- An Electrolytic Refinery in Wall Street 594
- A New High-Resistance Pyrometer 596
- Notes 596
- Personal 596
- Digest of Electrochemical U. S. Patents (prior to 1902) 597
- Book Reviews 598

Published by

McGRAW PUBLISHING CO., Inc., 239 West 39th Street, New York

MONEL METAL

Wire Cloth

for Laboratory and Plant

Made of Monel Metal, the *only natural nickel and copper alloy,* this screen cloth shows a wonderful resistance to strong acid and alkaline conditions.

Monel Metal Wire Cloth has already demonstrated such superiority to all other metals used for the purpose, that the United States Government has adopted it for window screening in the City of Colon at the canal operation, to withstand adverse climatic conditions.

This wire cloth gives splendid service in mines, chemical plants, sewage disposal plants, engineering operations, and trying manufacturing conditions where any other metal cloth would be quickly eaten away.

One concern that took a trial order from us six months ago has already taken in repeat orders 25,000 pounds of Monel Metal Wire Cloth.

We can fill promptly large or small orders for this Wire Cloth for any uses or conditions.

Remember this is but one of many Monel Metal specialties. In rods, castings, forgings and sheets this remarkable metal is now doing service wherever acid, alkaline or severe climatic conditions prevail; smelter roofs, pump rods, super-heated steam valves, pickling vats and frames, mine screens and scores of other places.

May we send you the "Biddle Bulletin" every month? Your name and address on a postal will put you on the mailing list.

Biddle Hardware Company

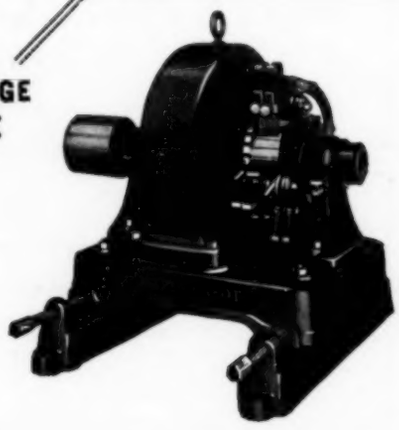
DISTRIBUTORS
Established 1837

512 Commerce Street, Philadelphia
150 Chambers Street, New York

Branch Offices
London Montreal Stockholm Buffalo

FOR ELECTRO-CHEMICAL WORK

HIGH AMPERAGE
LOW VOLTAGE



HOLTZER-CABOT

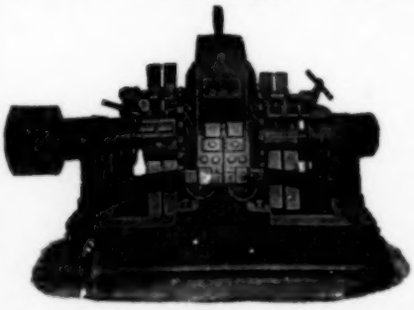
PLATING DYNAMOS

PLENTY of iron for magnetic circuits
PLENTY of copper for low temperature
PLENTY of satisfaction for our customers

Our bulletin 306 contains invaluable information

THE HOLTZER-CABOT ELECTRIC CO.
BOSTON - - - - CHICAGO

Low Voltage Generators



Up to 10,000 amperes

Single, two and three voltages for School and Laboratory work. Deposition, Refining and Separation of metals.

Chas. J. Bogue Electric Co.
513-515 West 29th, New York

ELECTROLYTIC LEAD REFINING

as adopted at Trail, B. C.; Chicago, Ill. and Newcastle-on-Tyne, England.

For Licenses in the United States, England, Germany, Australia and Mexico, address

ANSON G. BETTS, 16th Street North, Troy, N. Y.

Metallurgical and Chemical Engineering

A Consolidation of Electrochemical and Metallurgical Industry and Iron and Steel Magazine.

Vol. XI | New York, October, 1913 | No. 10

PUBLISHED MONTHLY BY THE
McGraw Publishing Company, Inc.

James H. McGraw, President.
C. E. Whittlesey, Secretary and Treasurer.
239 West 39th Street, New York.
Telephone Call, 4700 Bryant. Cable Address, Metchem, New York.

Western Office.....421 Boston Bldg., Denver, Colo.
Chicago Office.....Old Colony Building
Philadelphia Office.....Real Estate Trust Building
London Office.....Hastings House, Norfolk St., Strand

E. F. Roeber, Ph.D., Editor.
H. C. Parmelee, Western Editor.

J. M. Muir, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; for all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

Copyright, 1913, by the McGraw Publishing Company, Inc.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

New York, October, 1913.

CONTENTS.

Editorial:
Colorado Meeting of the American Electrochemical Society..... 535
Accidental Coincidences..... 536
Handling Slime at Anaconda..... 536
The Trend of Tube Milling..... 536
Steel Under the New Tariff..... 537
Readers' Views and Comments:
Continuous Counter-Current Decantation. By John V. N. Dorr.... 538
Hydrometallurgy—Joys of Its Theory, Woes of Its Practice. By Warren F. Bleecker..... 538
New York Section of the American Electrochemical Society..... 539
Iron and Steel Meeting of American Institute of Mining Engineers.. 540
Chicago Meeting of American Institute of Metals..... 540
American Institute of Chemical Engineers..... 540
New York Section of the American Chemical Society..... 540
Western Metallurgical Field..... 540
Iron and Steel Market..... 542
The Non-Ferrous Metal Market..... 543
A Study of the Oxidation of Coal and of the Process of Combustion. By Horace C. Porter..... 543
Corrosion Report Before the British Institute of Metals..... 544
Continuity Versus Atomism—The Limitations of the Scope of Physics and Chemistry. By Sir Oliver Lodge..... 545
Winona Stamp Mill. By R. B. Seeber..... 549
Quantitative Spectrum Analysis. By G. A. Shook..... 552
Mill Physiology. By Stephen L. Goodale..... 556
Determination of Oxygen in Copper and Brass..... 558
Annealing of Gold..... 558
Induction Furnace Notes. By Joh. Harden..... 559
Improvements in Smelting at the Consolidated Company's Works, Trail, B. C. By E. C. Jacobs..... 562
Electric Furnaces, Their Design, Characteristics and Commercial Applications. By W. McA. Johnson and George N. Sieger..... 563
The Quantitative Determination of the Precious Metals Gold, Silver and Platinum. By Trenkner..... 567
Volume Changes in Alloys..... 568
Phosphorus in Copper—Aluminum Alloys..... 568
Colorado Meeting of the American Electrochemical Society, with abstracts of papers by E. F. Northrup; Irving Langmuir, E. O. Adams, and G. S. Meikle; Jos. W. Richards; Edward F. Kern; G. Howell Clevenger and M. L. Hall; Dorsey A. Lyon and Robert M. Keeney; Frank S. MacGregor; S. C. Lind; W. McA. Johnson; Peter E. Peterson; Robert M. Keeney; Siegfried Fischer; O. L. Kowalke; F. Zimmerman; Alan Leighton; C. W. Bennett and C. O. Brown; Arthur J. White; Frank C. Mathers..... 569
Synopsis of Recent Chemical and Metallurgical Literature..... 591
An Electrolytic Refinery in Wall Street..... 594
A New High-Resistance Pyrometer..... 596
Personal..... 596
Digest of Electrochemical U. S. Patents (prior to 1902)..... 597
Book Reviews..... 598

Colorado Meeting of the American Electrochemical Society

In descriptions of the Cripple Creek railroad trip it is said that this trip "bankrupts the English language." With equal truth the same may be said of Colorado's overwhelming hospitality extended to the American Electrochemical Society at its meeting last month. A wonderful program had been arranged by the Society's Colorado friends, with the first meeting in Denver, the second at the University of Colorado in Boulder, the third at the School of Mines in Golden, a final session on top of Pike's Peak, an excursion to Cripple Creek, and a delightful series of social functions, sight-seeing trips, and visits to chemical and metallurgical works. Nothing but the "envy of the gods" could spoil this program, and when they sent a downpour of rain when there should have been a picnic dinner on Lookout Mountain, the ascent of the mountain was spoiled, but not the picnic dinner and not the enjoyment. In every other detail the program was carried out as projected, and those who attended the meeting will never forget it.

It was not the largest meeting, but it was the most spirited, the most lively, the most strenuous meeting the Society has ever held. This is true in every respect, not the least true with respect to the technical sessions. There were lively discussions and any casual onlooker would quickly have become aware of the fact that the Society is anything but a mutual admiration society. But in spite of freely expressed criticisms and spirited controversies, there never was a trace of personal ill-feeling, but due respect for the other fellow's personality. In the case of three or four papers, dealing with special phases of the relation of electrochemistry to metallurgy, the discussion lasted almost an hour. There would have been no possibility of finishing the program in the time allotted to the technical sessions if all the papers had not been printed in advance. Fortunately this is now a firmly established rule with this Society. As a detailed report of the proceedings, with abstracts of the papers, is given elsewhere in this issue, there is no necessity here to go into detail.

Certainly this meeting must have a lasting effect of far greater importance than would appear probable at first sight. The human reaction between the Western metallurgist and the Eastern electrochemist was vigorously started. This is the main thing. And what real use is there of a *national* scientific or engineering society but to act as the catalytic agent starting just such a human reaction? The spirit exhibited in the discussions in open sessions and outside of them indicates that the reaction velocity will be high. Of course the reaction must obey the laws of chemical mass action, and is reversible. As to what electrochemistry can do for the West, Western metallurgists have expressed their needs, hopes, and doubts; and time will show the outcome. As to what Western metallurgy

can do for Eastern chemistry, nothing was more suggestive than the inspection of the two cyanide mills in Colorado Springs and Victor.

Good luck to the Colorado Section of the American Electrochemical Society founded on top of Pike's Peak. It was founded not to detract from, or compete with, other societies. It has a glorious mission of its own.

Accidental Coincidences

A few weeks ago the *Engineering and Mining Journal* pointed out that during August there were, partly overlapping in their dates, the meetings of the American Institute of Mining Engineers at Butte, Mont., of the Lake Superior Mining Institute at Duluth, Minn., and the International Congress of Applied Geology in Canada; many persons who would have liked to attend all three of these meetings were unable to do so; it was urged that there ought to be a clearing house for society meetings, some central organization which might be consulted in the arrangement of dates, with the idea of avoiding coincidences.

This unfortunate condition of accidental coincidences now appears to become almost epidemic. In September on identically the same days the American Chemical Society held its meeting at Rochester, the American Electrochemical Society its meeting at Denver. This was purely an accidental coincidence. Probably it affected but little the attendance at either meeting. But, as a matter of principle, such a thing should be impossible.

In October there will be an overlapping of the meetings of the American Institute of Metals in Chicago with the iron and steel meeting of the American Institute of Mining Engineers to be held in New York on Oct. 16 and 17, and to be concluded by a banquet on the evening of Oct. 17, and on this same evening the New York section of the American Electrochemical Society will open the season with a meeting for which an excellent program has been arranged that should attract many iron and steel men.

Clearly something ought to be done. If a clearing house for society meetings can be created, let us have it as soon as possible. If any of our readers has a practical solution of this problem to offer, it will be welcome.

Handling Slime at Anaconda

As the result of a very elaborate series of experiments, it appears that the Anaconda Copper Mining Company has reached a conclusion as to the best method of handling the slime produced at the Washoe concentrator. We might almost use the term tentative conclusion, for any process adopted in this day represents only the present state of the art, and is subject to modification as further advances are made. As stated by Mr. Ralph Hayden, at the Butte meeting of the American Institute of Mining Engineers, the Anaconda problem is, briefly, to thicken daily about 20,000,000 gal. of slime pulp containing from 2 per cent to 3 per cent solids, producing simultaneously clear water for the subsequent concentration process, and a pulp containing from 10 per cent to 15 per cent solids. The second part of the problem is the concentration of the thickened pulp.

In the final decision as to the best method of accomplishing the desired end, two features stand out prominently: first, the adoption from the cyanide industry of a machine originally developed for the thickening of gold-bearing slime for agitation and filtration; and, second, the improvement and adaptation of one of the very oldest types of concentrating machines. Hitherto it has been considered impracticable, in work of the magnitude which obtains at Anaconda, to thicken slime and recover water by any other means than settling ponds of large area. The recent series of articles in this journal by Mr. H. N. Spicer showed this to be a world-wide practice; and indeed it has been the custom at Anaconda. Mechanical contrivances have been left out of consideration as being of inadequate capacity.

It, therefore, becomes of considerable interest in the realm of concentration, and particularly of slime concentration, to know that the Anaconda tests determined the use of the Dorr continuous thickener and the buddle, respectively, for preparing and concentrating the slime pulp. The thickening plant will be of special design to meet the particular needs at Anaconda; and the buddles will be twenty decks high to provide maximum capacity on a small ground area.

This brief recital of fact should be suggestive to men engaged in any branch of industry. It shows how the developments made to meet the peculiar needs in one branch may be adapted to the requirements of another. The recovery of clear water from 20,000,000 gal. of thin slime at Anaconda suggests, for example, the possibility of using mechanical means, instead of settling basins, for the preliminary clarification, at least, of some municipal water supplies, especially in those cities situated on muddy rivers. If only 90 per cent of the suspended solid was thus removed, there would be a saving of much labor now expended on filter beds.

The work at Anaconda also emphasizes a point frequently suggested, that in our progress we sometimes find it advantageous to revert to the machines and practices of an earlier date. The buddle is an old device, considered by some as obsolete and a relic of past practice; but here we find it rehabilitated to perform a useful function.

The Trend of Tube Milling

Comparison of the monthly reports of the Transvaal Chamber of Mines emphasizes the increasing importance of the tube mill in the equipment of a Rand cyanide plant. According to the figures for last June, the Consolidated Langlaagte has 100 stamps and ten tube mills, the ratio of 10:1 being the lowest of any installation reported. The highest ratio was 90:1 at the Durban Roodeport, but there were several instances of such ratios as 12, 16, and 20 to 1. The effect of this increased number of tube mills is noticeable in the daily stamp duty. At the Consolidated Langlaagte, a twenty-four-hour duty of 21½ tons per stamp was recorded; and while other factors obviously enter into this high stamp duty, such as weight of stamps and mesh of screens, we see a tendency toward much higher stamp duties by reason of the use of the tube mill as a secondary grinder. As viewed by the *South African Mining Journal*, the tendency on the Rand is toward heavier stamps, coarser screens and more tube mills per stamp.

It is apparent also that the long tube mill, originally adopted in metallurgy from the cement industry, is finding less favor and is being shortened, with consequent advan-

tage in reduced power consumption. This is true not only on the Rand, but also in this country. At one time Rand tube mills were "standardized" at 22 ft. by 5½ ft. More recently these dimensions have been changed to 16½ ft. by 6 ft. In Mexico experiments were made on a long tube mill by boring discharge holes at intervals throughout its length, and examining the products obtained after passing through different lengths of the mill. It was found that the first 16 ft. of a 22-ft. tube gave a product as good for the purpose desired as did the entire mill. Hence the length was accordingly reduced.

Two other features of tube-mill construction and operation now being adopted in this country are the tire-discharge and operation of mills in tandem. The tire-discharge is 18 in. in diameter, fitted with reverse spiral to prevent discharge of pebbles. The use of tube mills in tandem, with intermediate classification, has been found, in some cases, superior to a larger number of mills in parallel, treating the same tonnage of ore and yielding as good a product for cyaniding.

Steel Under the New Tariff.

The opposition of the American steel manufacturers to the great reductions in the tariff is popularly misunderstood, though not from there having been any lack of adequate explanation. Repeatedly the question is asked why American steel manufacturers should fear foreign competition within our borders when we are able to export 2,500,000 tons of steel products annually, in competition with the world. Answers have been given, but they are not generally heeded.

The American steel industry is placed in a position which would be untenable in a military contest. Imagine a people with an impregnable citadel and outposts located at random, some of which are much more accessible to the enemy than to those upon whom the burden rests of defending them. The people are able to make successful sallies with certain forces, say with cavalry, while with infantry they must keep strictly within their own borders. In war a new alignment would quickly be created. Some of the outposts would be lost. The cavalry would carve a way for the infantry.

The American steel manufacturer cannot so wage his warfare in the territory which geography seems to have given him. Important consuming markets are much farther removed from his centers of production, in point of cost of carriage, than they are from foreign ports. Costs of production are so aligned between American and foreign producers that the American manufacturer can send some products to the uttermost parts of the globe, while others must stay at home, and the first cannot open the way for the second. Steel pipe is readily exported, but merchant steel bars, except in the Canadian market, can rarely compete with the foreign producer.

For many years prices of the great majority of steel products have been based upon Pittsburgh as a basis, plus the rail freight to destination. This structure has been regarded as good, and the practical operation has been eminently satisfactory—to the steel producers and to the railroads. On an actual count one could probably easily find a million tons of steel products consumed in the United States in districts to which the freight from Pittsburgh exceeds the freight from foreign ports by a greater amount than the tariff duties hitherto levied upon such products. In the territory consuming those products the American mills are now, with the inconsequential duties enacted, placed at a great disadvantage, in that to meet foreign competition their realized prices at mill would be less than those of the best located foreign producers.

Again, there are great differences in the alignment of prices of different products. In the United States plates, structural shapes and merchant bars have lately been quoted at the same level, though until recently plates and shapes commanded $1 per ton more than bars. German bars at Antwerp, however, are quoted $3 a ton lower than German structural shapes, while the new tariff is lower on bars than on shapes, and the freights are the same on the two commodities, both our inland freights and those across the water. The fact that we can and do export structural shapes in large quantities cannot save use from a German sally into our territory with bars.

American manufacturers have been keener to improve their manufacturing methods than their selling methods. In the final analysis it may be that they feel much stronger in their mill cost structure than in their market structure. The market has been particularly sensitive to competition, and taking its whole history not infrequently savagely destructive competition. To protect themselves American sellers have resorted to artificial means, sometimes elaborate, sometimes relatively simple. Sometimes there has been no more control than that each manufacturer for himself desired to avoid departing from a price openly recognized as "the market." Such an adherence would be possible only were the price structure an extremely simple one, and thus easily understood, and the structure has been that of there being a Pittsburgh base price, delivered prices being in all cases the base price plus the rail freight to destination. Showing these rates large books have been published, whereby no misunderstanding can readily occur. With certain of the markets vastly more exposed than others to foreign competition, such a simple structure cannot be maintained, and adherence to regular selling prices by the mere volition of the individual manufacturer is made practically impossible by there being no recognized structure, unless the exposed markets are calmly resigned. Naturally the steel manufacturers have not been eager to emphasize that part of their objection to tariff reduction which the facts here indicated suggest, but that their dissatisfaction rests partly upon this foundation is rather plainly apparent.

However, we have been assured that to be faced with additional competition will brighten our wits and make us better men in the long run. The thought has been suggested chiefly with reference to our manufacturing methods, but we may find that our selling methods, which confessedly are not good in some respects, may also be improved even though the ordeal promises to be a trying one. Assuredly one of the effects of the lower tariff will be to increase the tendency toward competition between our own mills. No analysis of the prospects can avoid that conclusion entirely, though the superficial idea has been purely that additional competition would be forced between American mills as a class, and the foreign producers.

Readers' Views and Comments

Continuous Counter-Current Decantation

To the Editor of Metallurgical and Chemical Engineering:

Sir:—I note in your issue of September, in an editorial on the influence of South Dakota on cyanidation, a statement which would cause one to infer that the use of continuous counter-current decantation by John Randall in 1901 was a failure. Broadly speaking, if a plant shuts down it can be called a failure; but the following account of the circumstances connected with the plant will, I think, throw light upon the subject.

Mr. Randall, who is a very conscientious man, was approached by the owner of the property and asked to build a mill upon it for him. He protested that it would be much better to spend the money on further development of the mine; but when he found that the owner was intent on building a mill under any conditions, he finally consented to build it for him, and did so, developing there the counter-current method mentioned. After the mill had run for a month or so, the ore available was worked out and the rock furnished did not contain over $1 per ton, so that the plant was naturally forced to shut down.

After this happened I met the owner one day, and speaking of the property he said: "When a mill shuts down there are only two things to do, blame either the mine or the chemist. As I want to sell the mine in this case I have to blame the chemist."

If Mr. Randall had been fortunate enough to install the process the first time at a plant with a good supply of ore, it is most probable it would have kept running indefinitely, as Mr. Randall's ingenuity would doubtless have solved the various small problems that arose in developing the use of this method. There is no question, of course, but that the Dorr thickener cuts out all the troubles met with in cones, and is far preferable, but it would be unjust to say that the method without it was a failure.

John V. N. Dorr.

Denver, Col.

"Hydrometallurgy—Joys of Its Theory, Woes of Its Practice"

To the Editor of Metallurgical and Chemical Engineering:

Sir:—In the September number of this journal Dr. Regis Chauvenet has pointed out some pertinent facts and instances relating to hydrometallurgy. Inasmuch as this matter is of fundamental importance, I wish to present another perspective of the subject, in addition to pointing out some statements which, taken as representative, seem unfair to a branch of metallurgy along which so much has been accomplished, and of which so much is to be expected.

Notwithstanding the statements of the author to the contrary, the sum total impression one gains is that hydrometallurgy is a dangerous and fickle field—and one which offers particularly fertile soil to the charlatan, the ignorant chemist, or the unscrupulous promoter. There is no denying that, within the limits of poetic license, the facts as set forth are true, but the instances are scattered, and no process nor type is followed to a logical conclusion.

First of all, it should not be inferred that all of the impossible proceses and inventions of a chemical nature have been in the field of wet metallurgy. A few years ago I witnessed a brilliant electric furnace operation which outclassed the broadest claims of either the Wynne process or the treatment of Herkimer sand.

Another example of the reduction of a staple product without a reducing agent has been so recently well advertised as to need no more than passing reference.

A Western genius not long ago devised a roaster which not only prepared the noble and base values for quantitative separation, but delivered the gangue ready for sale as cement. I think they hope to save most of the potash, too.

It is also within the memory of man that a process for the manufacture of diamonds was sold for a large sum; that a tragedy resulted from the belief of the claims that gold could be made out of baser metal; and that a very smooth gentleman convinced moneyed men that aluminium could be reduced with carbon.

The author specifically omits the cyanide process since "it constitutes a class by itself." Yet some of the greatest swindles ever devised were based upon the successful reputation of cyanidation. A rather large scale failure of a cyanide process (absolutely honest in this case) has just been announced. Another case of cyanide failure is in Boulder County, Colorado (there have been several failures in that locality). A very large mill was built at a cost reported to be in the general magnitude of a quarter of a million dollars. The pegmatite dyke which was to supply the ore contains, to my positive knowledge, as little gold as the sea water mentioned by the author. Almost all of these cyanide propositions begin in the same way—a large body (a prospect hole, in most cases) of low-grade ore, a 10-ton mill with a little tin-whistle roaster. The mill starts with a grand splurge, but screens refuse to work, the crusher breaks a jaw, the screw conveyor fails. During the weary months of getting started the manager convinces his stockholders that the mill will pay exactly three times as much on 30 tons per day as the 10 tons first proposed. Then a 50-ton unit, and finally, if the insurance companies do not get the mill, another ambitious promoter gets the machinery and the story begins again.

Yet the cyanide process has yearly added millions to our wealth.

It seems particularly unfortunate, therefore, that the author should have selected hydrometallurgy as the field in which impostors and half-learned chemists chiefly operate. There are unprincipled men and quacks in all branches of chemistry and metallurgy, and in mining. Keeley motors, gas burners which consume nine parts of air to one of gas, wonderful vacuum pumps which lift 2-ft.-lb. of water with 1-ft.-lb. of energy expended, marvelous tunneling machines, all attest the exploitation by fakirs of other fields as well.

The author's remarks on the relation of the laboratory process to the mill process are to the point, and they are true without exception so far as I know or can imagine. Yet if we accept the spirit of this article we shall be buried in a swamp of pessimism so deeply that only the most pressing need can force us to emerge. It is given no man to foresee the difficulties and pitfalls which lie between the laboratory and the finished mill. But by persistent labor, careful observation, and unfailing optisism, a successful end is not only possible but probable.

I disagree most thoroughly with the author when he speaks of fallacy. There is no magic in laboratory operations. The relations between cause and effect are the same wherever matter exists. The difficulty is that some men try to imitate laboratory apparatus in planning reactions on a large scale. A bubble of gas coming up through a beaker means only a million bubbles coming up in just the same way in a very large vessel. Boiling means a gas burner underneath. How queer to think of forcing hot gas or steam into a tank of liquor—especially if one never thinks of it. If a fallacy exist, here it is; the mind of a monkey trying to grasp original problems. We are all like monkeys in many ways. We can't quite forget how the other fellow does it.

An intelligent worker may, by treating quantities of one gram or less, draw valuable and correct conclusions. The experienced metallurgist will always avail himself of this opportunity. But here lies a dangerous trap for the tyro; he overrates and underrates the order of magnitude—he cannot prop-

erly control his imagination. On the other hand, the careful metallurgist will not be far misled by the phenomena attendant upon gram-lot treatments. But rather, having gained a large amount of information from working in a small way, he is well prepared to proceed with larger quantities. After one has worked with 1 gram, 10 grams, 100 grams, he may deem it profitable to work with a pound or 10 pounds.

These operations, while they check up the work done in the smaller way, do so only incidentally—they are for the purpose of obtaining additional data upon which further conclusions may be based. Broadly speaking, the gram experiments are qualitative, the pound experiments quantitative.

Also shapes, sizes and materials of apparatus begin to crystallize out, systems of heating and agitation may be tried, and a general idea may be had of ease of filtration and washing, together with a conception of the relative bulk and treatment of secondary products. Each experimenter will have different methods of approach and different technique, but there are certain well-defined endpoints which everyone must reach before proceeding to a finished process. The man who omits to study the solvent effect of his solutions upon everything with which they come in contact might as well go to selling lightning rods again.

Again, there are certain standard operations, the practice of which the metallurgist may correctly assume to fit into his proposed process without difficulty. Among these may be included crushing, screening, roasting, pulverizing, heating, agitation, decantation, filtration, absorption, drying, sampling, the application of power and electricity, and classes of materials. These things have all been studied and standarized. There is no need of inventing a vacuum filter if men who have spent their lives in the business offer you the best they have. I knew a man once who prided himself upon having invented every piece of apparatus in his plant. He had spent thousands of dollars needlessly, and had inferior stuff in the bargain.

In the laboratory a gram of material is digested in a glass beaker over a gas burner. Fortunately we have no large glass tanks to contend with in practice. And what a blessing we cannot put a burner under a 600-ton tube to heat it. But the chemical engineer knows that there are means of boiling solutions efficiently, and that there are to be had containers of any desired size or shape for the treatment of almost any solution, be it alkaline or acid.

A diligent perusal of advertisements in reputable scientific journals will keep the metallurgist well informed as to almost all standard apparatus. The successful metallurgist who does not read advertisements is a genius of the highest type who could increase his efficiency 25 per cent by the simple formula above.

I do not think the sarcastic remark "Multiply the last figure by 100—and there you are" is warranted by the conditions stated. If the author is speaking of fakirs and ignorant persons who call themselves chemical engineers, he should not blame the system of hydrometallurgy. If he wishes to criticise hydrometallurgy fairly, he should at least employ in his theory the services of men of experience and common sense.

In answer to his question, "How many experts per ton?" I should without hesitation say, "One expert per gram, and let him stay with that gram until he has finished." It is at the gram stage of operation that the expert density should be high, in order that time, money, and materials may be conserved.

"A stoppage—arose from the sudden discovery that a certain element was present in solution which had no business there." (This sounds like calcium sulphate in the Malm process referred to.) Assuming the explanation correct: "Possibly the solution—constituted the solvent" I should say the preliminary work in about the pound stage had either never been done or else had been done in a very slipshod manner.

If each and every reaction has been tested out thoroughly and independently before the process is correlated; if the results are entirely satisfactory; there still remains the wearing off of the rough edges of the machinery and apparatus, and what is still more important, the training and discipline of the working force—from the superintendent to the beaker boy.

After this stage has been reached, the stockholders and friends may be invited to tea and cigars while the button is pressed for the long-expected opening. Generally the date is set for this button-pressing business about the time the concrete is poured for the foundations, and the general feeling is that the stockholders must not be disappointed for the n'th time. When they do come, it is a fortunate superintendent who hasn't a half dozen such experiences as recited by the author.

The statement relating to low efficiencies and recoveries is, of course, correct, but it is not denied by anyone excepting those whose opinions do not matter. Because the actual recovery of values is low is no cause for alarm. Processes yielding as low as 20 or 30 per cent of the original value may be commercially very successful. I could name at least three processes in which the net efficiency is under 50 per cent, but which have netted millions of dollars in real money.

I consider the comparison which the author has made between wet processes and smelting processes to be extremely unfair. It is true that a smelter can absorb almost all classes of ore economically. It is also true that a wet process can be usually applied to not more than one class of ore. But one cannot condemn hydrometallurgy because it is not a cure-all. A smelter is necessarily a large unit—larger than the average mine or group of mines can supply. The wet process on the other hand may be applied with efficiency and economy to relatively small bodies of ore.

The honest mine with real ore in it can usually obtain a suitable process. It does not need to worry over the possible discoveries of other mines or other kinds of ore. If the ore is not blocked out, the erection of a mill is wildcatting. If it is blocked out, then work out a process for what exists. Of course, if it is desired to have a process which will absorb all kinds of ore, why not make it broad enough to save the aluminium, potash, and zirconium. It is merely a matter of degree, just the same as a high recovery of values. It is a simple matter to get a recovery of 99 per cent if one cares to pay the price.

For example, the Malm process spoken of is designed to treat sulphide ores. The theory (the most successful part of the process) excludes oxides and carbonates. What sane man, therefore, would try to chloridize an oxide or carbonate under the conditions described?

If the metallurgist has seen to it that he has a fair sample of the ore as it exists, and works out a process on that ore, he has been successful. If the mining engineer was mistaken, or if a new ore body is opened up, it is asking too much to require a process to be of such prophetic nature as to adapt itself to the new unknown conditions.

Excepting by inference, I have not spoken of the possibilities of the application of electricity to hydrometallurgy; yet in the years to come it may be predicted that the advance of these two, hand in hand, will be rapid. Given plenty of good water, salt, sulphuric acid, soda ash, and electrical energy, the metallurgist of to-day and to-morrow will assure hydrometallurgy an exated position not surpassed by any other method of winnng the vaues from raw ores.

Canonsburg, Pa. WARREN F. BLEECKER.

New York Section of the American Electrochemical Society

The first meeting of the season will be held at the Chemists' Club, 52 East Forty-first street, New York City, on Friday, October 17, at 8.30, and will be preceded by an informal dinner at the same place at 7 p. m.

The subject for the evening is **some applications of the microscope to industrial work,** and the program is as follows:

Metallography of Carbon. By G. A. Roush, Lehigh University.

The application of the principles of metallography and petro-

graphy to the identification and analysis of carbon products, showing the development of characteristic structures and the utilization of these structures in identification and analysis.

The Microstructure of Raw and Manufactured Copper. By W. H. Bassett, American Brass Co.

A series of pictures showing structure of cast copper and how this structure is altered by rolling, etc.

The Microscope in Mineralogical Analysis. By Gilbert Rigg, New Jersey Zinc Co.

A series of Lumiere plates showing microphotographs of zinc ores with resolution of the minerals present.

Some remarks on Micrometry as Applied to Alloys. By Dr. C. H. Mathewson, Yale University.

The use of micrographic methods in investigating questions of constitution, qualitative and semi-quantitative interpretations; structural relations which are favorable to the development of micrometric methods; advantages and short-comings of such methods in ordinary analytical practice; the determination of cuprous oxide in copper; of iron in zinc.

These lectures will all be well illustrated by lantern slides and photographs. Any member is welcome to bring guests who may be interested.

Mr. Lawrence Addicks, of Chrome, N. J., is chairman of the New York Section of the American Electrochemical Society, and Mr. H. B. Coho, 111 Broadway, New York City, is secretary-treasurer.

Iron and Steel Meeting of the American Institute of Mining Engineers

The October meeting of the American Institute of Mining Engineers, which is to be held under the auspices of the Iron and Steel Committee, will be held on October 16th and 17th, 1913, in the United Engineering Societies Building, New York City. Members of friendly societies are invited.

The program for the meeting is as follows:

First Session, October 16, 1913, 10 *A. M.*

W. A. Forbes, Blast Furnace Gas Cleaning.

W. H. Blauvelt, The Slagging Producer.

F. Peter, The Generation of Steam by Waste Heat from Furnaces.

G. C. Stone, The Generation of Steam by Waste Heat from Regenerative Furnaces.

W. R. Shimer, Over-Oxidation of Steel.

Second Session, October 16, 2 *P. M.*

H. F. Miller, Jr., New Design of Regenerators for Open-Hearth Furnaces.

Richard K. Meade, The Use of Powdered Coal as Fuel.

H. R. Barnhurst, The Use of Powdered Coal as Fuel for Metallurgical Furnaces.

W. S. Quigley, The Use of Powdered Coal as Fuel.

E. Stuetz, The Scoria Process for the Manufacture of Fine-Ore Briquettes.

Felix A. Vogel, Briquetting.

Felix A. Vogel, Use and Advantages of Briquettes in Blast Furnace Practice.

R. H. Lee, The Use of Nodulized Ore in the Blast Furnace.

Third Session, October 17, 10 *A. M.*

H. M. Howe, Discussion of the Existing Data as to the Position of Ae_3.

H. M. Howe and A. G. Levy, Determination of the Position of Ae_3 in Carbon-Iron Alloys.

H. M. Howe, Ae_1, the Equilibrium Temperature for A_1 in Carbon Steel.

G. K. Burgess, J. J. Crowe and H. S. Rawdon, Thermal and Microscopical Examination of Professor Howe's Standard Commercial Steels.

H. M. Howe, The Divorcing of the Eutectoid in Meteorites.

Fourth Session, October 17, 2 *P. M.*

R. R. Abbott, The Influence of Various Elements on the Absorption of Carbon by Steel.

J. V. Emmons, Some Phase of the Practical Treatment of Tool Steel.

W. E. Ruder, Grain Growth in Silicon Steel.

J. H. Hall, Shock Tests of Cast Steel.

G. H. Clevenger and B. Ray, The Influence of Copper Upon the Physical Properties of Steel.

J. H. Hall, The Life of Crucible Steel Furnaces.

Mr. H. M. Boylston, Abbott Building, Harvard Square, Cambridge, Mass., is the secretary of the Iron and Steel Committee of the Institute. Mr. Bradley Stoughton, 29 West 39th street, is the secretary of the Institute.

Chicago Meeting of the American Institute of Metals

The next meeting of the American Institute of Metals will be held in Chicago, Ill., from October 13 to 17. The hotel headquarters will be at the Hotel LaSalle.

The arrangement of the meeting is in the hands of a committee with Mr. Gillett as chairman. Among the papers announced so far are the following: Soldering Fluxes for Soft Solder, by Walter Arthur; Core-Room Economies, by O. F. Flumerfelt; Report of the Official Chemist, by Arthur D. Little, Inc.; Brass Foundry of the Future, by G. P. Karr; the Boiling of Metals, by J. W. Richards; Producer Gas, as Applied to Brass Melting, by E. F. Bulmahn; Internal Strains in Castings, by J. E. Howard; the Work in Metals of the Bureau of Standards, by G. K. Burgess; discussion on the Nomenclature of Non-Ferrous Alloys, lead by G. K. Burgess; Approximate Melting Points of Some Commercial Copper Alloys, by Norton and Gillett.

Mr. W. M. Corse, Lumen Bearing Co., Buffalo, N. Y., is the secretary of the Institute.

American Institute of Chemical Engineers

The annual meeting of the American Institute of Chemical Engineers will be held in New York City from December 10 to 13.

Prof. John C. Olsen, Polytechnic Institute, Brooklyn, N. Y., is the secretary.

New York Section of the American Chemical Society

The first meeting of the season will be held in the Chemists' Building on Friday evening, October 10th, and will be opened by an address by the chairman of the Section, Dr. C. B. Hesse.

This will be followed by a paper by F. J. Pond, on a review of the pioneer work on the synthesis of rubber.

Mr. C. M. Joyce, Arlington, N. J., is the secretary-treasurer of the Section.

The Western Metallurgical Field

Status of Labor Strikes

Although conditions in the copper country of Michigan have been improved since the first disturbance incident to the labor strike called by the Western Federation of Miners, they are yet far from normal and it will be months before the various companies are operating at their usual capacities. Indications are that the strike has been broken. The Calumet & Hecla is hoisting and treating some ore, and other companies have resumed production on a small scale.

The operators held firmly to their decision not to recognize or treat with the Federation, and in a letter to the Governor of the State have set forth reasons for their refusal to accept his suggestion for a conference between representatives of the companies and the miners. The companies stated that they believed they were conserving the best interests of the miners as well as of the mining industry by refusing to accept the demands of the Federation. In defense of their attitude they cited the past record of the Federation and stated it as their belief that their miners had been misled by an organization which has been discredited in other mining districts.

Late advices indicate that the Federation is inclined to yield recognition of the union. President Moyer and some other officials have visited the Governor and suggested arbitration

of the points at issue, eliminating the question of recognition, but the outcome of the conference is not known. Disturbances of a minor nature have continued throughout the strike, some resulting in bloodshed. Troops are still in the district, and the mounted patrol has been increased in order to cope with the situation.

The labor strike in southeast Missouri is reported to have been settled, based on an increased wage to the miners without recognition of the union. The first demand was for an increase of 50 cents per day, but later this was reduced to 20 cents, which was considered more favorably.

Probable New Copper Smelter for Nevada

The Consolidated Coppermines Company is the name of the corporation into which were merged the Giroux Consolidated, Butte & Ely, Chainman Consolidated and Coppermines companies, all in the vicinity of Ely, Nev. Following the exchange of stock in the old companies for that in the new, according to terms of the merger, the new company has arranged a bond issue of $2,500,000. The purpose of this latter fund is stated to be, among other things, "for carrying on simultaneously a comprehensive series of experiments with a view of determining the method of securing the highest percentage of extraction of metals and at the lowest possible cost; and when such methods are determined, for designing, constructing and equipping an adequate concentrating and smelting plant for the treatment of the ores of the Consolidated company and any customers it may have."

In consideration of what has been announced, and the later activity of the company's agents in securing a suitable site for works, it would appear that a new concentrating and smelting plant will be constructed. The old question of smelter fume and damage to country surrounding the smelter is entering into the selection of a site. Both the company and the inhabitants of Ely seem desirous of having the new works located near to that town. In an effort to protect itself against future trouble, the company has been securing from the inhabitants of Ely and vicinity, waivers against damage from smelter smoke. Little difficulty is met in securing such waivers, although objection has been made to the fact that the nature of the agreement does not obligate the smelting company to adopt any device now known or to be invented whereby the damage arising from smelter smoke could be abated.

Leaching Experiments

Interest continues to be manifested in the leaching of copper ores and more companies are constantly making experiments. The work at different points in Montana and Arizona has already been alluded to, and holds out promise of success. More recently the Miami copper company has announced that a leaching process is to be given a trial in an experimental unit of 20 tons capacity. This work will temporarily set aside any experiments with flotation, and all effort will be made to improve the present system of concentration supplemented by leaching. It is anticipated that success along these lines will reduce the percentage of copper in the tailings from 0.8 per cent to 0.2 per cent. The sixth unit of the mill is even now making a better recovery than is obtained in the other five, due to some alterations.

Another company which has announced its intention of experimenting with leaching is the Nevada Douglas Copper Company. According to a statement by the president, several carloads of ore will be shipped to Denver, where the experimental work will be done in a plant that is already partly equipped. Following the completion of the tests, a large plant is to be designed for erection at the mines. At present the company has a contract for the smelting of its ores by the Mason Valley smelter, and it is the intention to have the new leaching plant completed before that contract expires.

American Mining Congress Philadelphia Meeting

During the week of Oct. 20 the American Mining Congress will hold its annual convention in Philadelphia. The meeting promises to be of unusual interest, in that the Western metal mining interests are to be as fully represented as the coal mining industry. Among the principal topics for discussion will be that of mine taxation, which is a matter that has agitated the mining industry for some time. It is expected that the discussion will elicit definite information on an equitable and scientific method of taxing mines and their output. Other matters of Western importance which will be discussed are a definite policy concerning the development of Alaska, the smelter smoke question and the disposal of debris from placer mining. The question of federal aid to mining education also will be on the program.

A new feature of the meeting will be the first mining exposition. This is a matter that has been agitated for previous meetings, but has never been brought to pass. At this meeting, however, arrangements have been made for the exhibition of mining machinery, demonstration of processes, methods adopted for the prevention of accidents in mines and mills, and provisions for rescue work in case of coal-mine accidents. The exposition will be held in Horticultural Hall, and is expected to add distinct interest to the meeting of the Congress.

Brown Cyanide Process Decision

The suit of Joseph A. Vincent vs. Tonopah Milling Company of Nevada and Desert Power & Mill Company, in the United States District Court for the District of Delaware, has been decided by Judge Edward G. Bradford in favor of the complainant, who alleged that the defendant was infringing the cyanide process patent of Alden H. Brown. The patent in question relates to an improvement in cyaniding precious metal ores, and has special reference to the sequence of the several steps by which the metals are recoverd by cyanidation and concentration. Customarily, an ore requiring both concentration and cyanidation is subjected to treatment in the order mentioned. Brown's patent covered the reverse method, viz., cyanidation followed by concentration. It was the patentee's idea that his process would effect a greater recovery of finely divided gold and silver, by dissolving them immediately in cyanide solution, rather than attempt their recovery by concentration before cyanidation, and thereby subject them to probable loss.

The claim on which decision was given is as follows: "The herein described process for the treatment of ore, consisting in first, pulverizing the ore in the presence of cyanide solution; second, subjecting the ore to hydraulic classification by the introduction of cyanide solution at the bottom of an overflow tank to produce an ascending current; third, leaching the ore by the use of cyanide solution, whereby the finer metal content of the ore is dissolved; fourth, removing the dissolved metal from the ore in any suitable manner; and finally subjecting the residue to concentration."

The court held that in effect the process used at Tonopah was an infringement on this process, and sustained the patent in suit. On its face the decision may appear to be of wide importance, but it doubtless will be reviewed by a higher court, after which its true import will be more apparent. It will be observed, however, that one of the steps in the process is hydraulic classification of sand and slime, against which it would appear that mechanical classification could be successfully substituted. Again, it would be possible to evade the stated sequence of the steps of the Brown process, and still do good metallurgical work. Crushing might be done in water, with subsequent dewatering of the pulp before cyaniding; or the sequence of cyaniding and concentrating could be changed without material loss. In short, it would appear that the Brown process is so clearly defined as to successive steps that few mills would find it impossible to avoid infringement without material loss. General practice is not in accord with the Brown process, and in any event there would be only a few special cases amenable to the decision.

Company Reports

From the twenty-eighth annual report of the Mount Morgan Gold Mining Company, Mount Morgan, Queensland, for the year ending May 31, 1913, the following interesting facts are

taken. The tonnage treated, grade of ore and metal recovered are shown in the table:

	Tons treated	Copper %	Gold dwt. per ton	Copper tons	Gold oz.
Copper ore	203,777	3.41	9.50	6,958	96,852
Gold ore	19,895	2.66	18.93	530	18,831
Many peaks	88,396	1.52	.15	1,346	658
Purchased ores	353	11.37	5.41	40	96
Miscellaneous products	9,677	4.19	4.24	406	2,051
Total and average	322,098	2.88	7.36	9,280	118,488

In addition to above gold, 7594 oz. was recovered from cleaning up the Mundic works which had been dismantled, as stated in the last half-yearly report.

Many minor improvements have been made at the smelting plant during the year, all of which have contributed to better operation. The large increase in wages, however, have shown their effect in an increased cost of smelting. New converters were installed during the year, but owing to trouble in the power plant, they have not been worked to the best advantage. The company has arranged for the purchase of 100,000 tons of iron ore for fluxing purposes, so that a large quantity of silicious ore in the mine can be treated. There is about 1,000,000 tons of such silicious material.

The old Mundic works have been completely dismantled, and the erection of a new 500-ton concentrating plant is well under way. It is expected that ultimately the capacity of the plant will be brought up to 1000 tons daily. Before designing this mill an experimental unit was run for some time and will continue for some months more. It has been found necessary to resort to finer grinding than usual on account of the intimate association of the minerals. The sum of $15,000 has been spent on concentration experiments, and further investigations will be made, particularly with reference to American practice. Good progress is being made on the new smelting works and power plant.

The Iron and Steel Market

September has been a month of declining activity marketwise. August has shown a clearly perceptible improvement over July, apparently presaging further improvement in September owing to the close of the midsummer period, in which business is normally dull, for the first half of September showed slightly less activity than August, and after the middle of the month almost complete stagnation suddenly appeared. Orders grew less, specifications on old contracts decreased, and buyers ceased to show any interest at all in the future. Throughout the industry it was at once noticed that a change had occurred, though it was difficult to determine the cause.

The more common view is that the imminence of the passage of the new tariff bill was responsible for the change. For months the knowledge that the bill would eventually be passed has operated to curtail forward commitments, and the buying has been only against definite wants, the filling of which could not be deferred, but it appears that buyers still had a little leeway, and could curtail their orders further. There is no evidence that actual consumption has decreased materially, though in a couple of months the major part of the railroad business on books will have been completed and in other directions there will be curtailment on account of the closing of the outdoor season. These influences would not be sufficient to explain the present stagnation.

Since about the first of the year, or just after the culmination of the great buying movement of 1912, the inflow of new business in steel products has continuously been less than the current shipments, but the mills had an accumulation of old business from which to draw. While this supply is not exhausted the mills have caught up and the remaining business on books can only be shipped at certain rates, in accordance with the requirements of consumers. Furthermore, a considerable portion of the business on books is subject to cancellation if the buyer can secure a better price elsewhere, for most contracts in the finished steel trade are lightly regarded. Already there have had to be many adjustments on contracts in force, and with the outlook grown much more uncertain as to prices buyers are still more chary as to placing specifications on contracts.

With mills now fully caught up on their old business, and with new business coming in at a relatively low rate, curtailment of output is practically inevitable. There have been few if any definite closings, but many mills probably operated under somewhat reduced pressure in September. Owing partly to weather conditions, actual output in the past three months has been at about 90 per cent of full rated capacity, and the outlook is that production will probably drop to between 75 and 65 per cent of capacity before the close of November.

Thus far the general level of prices have declined but slightly. Pig iron has not declined at all, while billets and sheet bars have declined $2 to $3 a ton in two months, and finished steel products have softened quite generally, though declines in openly quoted prices are recognized only in plates and shapes to the extent of $1 a ton, and in black and galvanized sheets to the extent of $2 a ton, such declines having occurred in September.

Both the advent of the new tariff and the fact that the mills can no longer operate at full capacity with the amount of business currently offered dictate that there shall be declines in prices and the next two months will probably witness some marked recessions. The tariff revision necessitates some important revisions, though how far they will extend is a question, the situation being a very complicated one. The American price structure rests upon a Pittsburgh basis price, plus rail freight to destination, these rates being many dollars per ton to the Pacific coast and to southwestern and southern points, while freights from foreign ports vary but slightly. Extras for size, section, etc., above base prices vary greatly between American and foreign products, and thus a great deal of study and negotiation will be necessary before the real competitive basis can be developed. The American mills do not intend to allow any large tonnage of foreign material to come into the United States, but as some semblance to the present price structure, in the matter of delivered prices, must be maintained there will probably be importations of some moment, chiefly for districts well removed from Pittsburgh.

Production of pig iron in the United States in September was at the rate of about 30,000,000 tons per annum, made up of about 21,500,000 tons by the steel works furnaces and 8,500,000 tons by the merchant furnaces. The total production thus shows a decrease of about 12 per cent from the maximum rate attained earlier in the year.

The steel works furnaces have lost about 8 per cent from their maximum rate and the merchant furnaces about 15 per cent from their maximum.

Even with a greater curtailment in output during the remainder of the year than now seems in prospect new tonnage records will be made by the calendar year in pig iron, steel ingots and finished steel prooducts.

Rolled iron will probably show a further decrease. Its output has been decreasing for several years.

Pig Iron

The pig-iron market showed a slight advancing tendency in the fore part of September, and with the stagnant condition of late in the month such advances as had been scored were not lost, but at the close of the month the tendency is in the direction of stationary prices. Production seems well regulated to demand. Statistics privately gathered show a slight decrease in stocks during August, and total stocks relatively small. Southern iron advanced 75 cents a ton during September, while at Philadelphia and Cleveland there were advances of about 25 cents. The current market stands as follows: No. 2 foundry, f. o. b. Birmingham, $11.50; No. 2 X, delivered Philadelphia, $16; No. 2 X, f. o. b. Buffalo furnaces, $14; No. 2 foundry, delivered Cleveland, $14.75; No. 2 foundry, f. o. b. Chicago furnaces, $15; at valley furnaces (90 cents freight to Pittsburgh and Cleveland) Bessemer, $15.75@$16; basic, $14; No. 2 foundry, $14; malleable, $14.25, and forge $13.50.

Steel

The market in unfinished steel has been softening, particularly during the second half of September. Sellers had consumers fairly well booked on contracts, but upon these they have had to make a number of readjustments. Generally these have been effected quietly, and relatively little inquiry has come into the market so that prices are not well developed. Formal offerings have been refused of billets at $24 and sheet bars at $25, either Bessemer or open-hearth, f. o. b. maker's mill, Pittsburgh or Youngstown, so that the market is not quotable above this level. Rods are available at $27, Pittsburgh or Youngstown, with few if any takers. In the east the market is quite at sea since billets are free under the new tariff and former asking prices of mills cannot be secured within several dollars a ton.

Finished Steel

Openly quoted prices on shapes and plates declined $1 a ton in September, and on sheets $2 a ton. Prices quoted below represent the open figures, with considerable shading in the majority of products, rails and sheets being exceptions. Prices are f. o. b. Pittsburgh unless otherwise stated:

Rails, standard sections, 1.25 cents for Bessemer, 1.34 cents for open-hearth, f. o. b. mill, except Colorado.

Plates, tank quality, 1.40 cents.

Shapes, 1.40 cents.

Steel bars, 1.40 cents, base.

Common iron bars, 1.55 cents, Pittsburgh; 1.25 cents at eastern Pennsylvania mill; 1.32½@1.35 cents delivered Philadelphia; 1.35 cents, delivered Chicago.

Wire nails, $1.65, base; plain wire, 1.45 cents, base.

Sheets, blue annealed, 10 gage, 1.60@1.65 cents; black, 28 gage, 2.05@2.15 cents; galvanized, 28 gage, 3.10@3.20 cents; painted corrugated, 28 gage, 2.25 cents; galvanized corrugated, 28 gage, 3.15 cents.

Merchant steel pipe, 80 per cent off list for ¾ to 3 inch.

Steel boiler tubes, 3½ to 4½ inch, 69 per cent off list.

Standard railroad spikes, 1.65 cents, Pittsburgh; 1.70 cents, Chicago.

Button head structural rivets, 1.90 cents; cone-head boiler rivets, 2 cents.

The Non-Ferrous Metal Market

Since our last report the prices for non-ferrous metals have advanced appreciably, and at the time of writing the upward tendency is still noticeable. The settlement of the labor strike in Missouri has brought that district into production again, and the market for lead has been easier.

While the prices quoted herewith are all higher than those which were quoted a month ago, still higher prices have ruled in the interim.

Copper.—Business has been divided between foreign and domestic consumers. The quotations on Lake copper are only nominal, as there is none of this metal in the market except that offered by Calumet & Hecla.

Electrolytic copper is quoted at 16.65@16.75 cents, and Lake at 17 cents.

Tin.—This market was more active during the earlier part of the month, but was extremely dull toward the latter part. The last quotation is 42⅝ cents for September tin.

Lead.—This market is quiet, though prices rule higher than a month ago.

St. Louis lead is quoted at 4.60@4.62½ cents, and New York at 4.70@4.75 cents.

Spelter.—Prices for spelter have ruled higher than here reported. At present the market is quiet and prices are lower. St. Louis is quoted at 5.55@5.60 cents, and New York, 5.70@5.75 cents.

Other Metals.—Tariff legislation has affected conditions in the market for aluminium and antimony. Little business is being done. New York quotation on aluminium is 22@22½ cents per lb.; and on antimony the prices range from 7.15 to 8.50 cents for various brands. Quicksilver is quiet and prices easier. New York quotes $39 per flask of 75 lb.; and San Francisco $39 for domestic, and $36.50 for foreign orders.

A Study of the Oxidation of Coal and of the Process of Combustion*

By Horace C. Porter

It is well known from the work of several investigators in European laboratories[1] and from earlier work at the Bureau of Mines that all coals unite with oxygen more or less at ordinary temperatures. The action is at ordinary temperatures largely a simple addition, very little gaseous products of combustion being produced. There is, however, a development of heat by the simple addition of oxygen, and this heat development is the primary cause of spontaneous combustion.

As the temperature rises, the oxidation reactions increase rapidly in rate, and the simple-addition reaction becomes complicated with the development of water and oxides of carbon as products of the oxidation and with the production of water and of methane and other gases by destructive distillation.

Under whatever conditions coal burns, as for example on the fuel bed of a boiler furnace or in suspension as dust in the air of a mine, the earlier stages of oxidation proceeding at the lower temperatures have important bearing on the ease of ignition of the fuel and the degree of inflammability of its dust. In order to throw more light on the nature of the combustion reactions at successive stages and to determine how the various kinds of coal differ in their rates of reaction with oxygen, a laboratory study has been made of the oxidation of coal, at temperatures ranging from 80 deg. to 300 deg. C.

A series of experiments has been run with samples of different coals placed in atmospheres of pure oxygen at a pressure reduced so as to equal the average partial pressure of the oxygen in air. The rate of absorption of oxygen by the coal was determined by admitting pure oxygen at such a rate as to maintain constant pressure in the apparatus. Large differences in rate were found between different kinds of coal, and the comparative oxidation rates thus found conform in general to the known comparative degrees of inflammability of these coals.

At temperatures above 200 deg. C. the production of CO_2 and other gases causes a considerable error in an experimental method which does not remove these gases as they are formed. A rapid-stream method was, therefore, devised in which weighed samples of dry coal were heated at definite temperatures in a rapid stream of dry air for one hour, the change in weight of the coal being accurately determined as well as the amounts of H_2O, CO_2 and CO produced. From these data the total oxygen used and the oxygen fixed were calculated.

It was shown that the oxidation of coal consists in the earlier stages of the formation of an unknown complex of the coal substance with oxygen, and the more or less gradual dissociation of this complex as the temperature rises into water, CO_2 and CO. Below 200 deg. water is the chief product of this dissociation, the proportion of CO_2 in the products increasing as the temperature rises. Carbon monoxide is a primary product of the oxidation of coal at temperatures between 100 deg. and 300 deg. C. and possibly also outside of this range. Triangular diagrams representing the relationship of the three products H_2O, CO_2 and CO at different temperatures show interesting tendencies, *e.g.*, toward constancy in ratio between CO_2 and CO within a certain temperature range.

The production of water by oxidation of coal at 100 deg. C. or lower is of interest in connection with the devising of methods for accurate moisture determination in coal. The direct production of CO at moderate temperatures is of interest in connection with mining operations and the storage of coal.

*An address delivered at the annual meeting of the American Chemical Society, Rochester, N. Y., Sept. 9-12, published by permission of the Director of the Bureau of Mines.

[1]Boudouard, Fayol, Richters, Anderson and others.

Corrosion Report Before the British Institute of Metals

The autumn meeting of the (British) Institute of Metals—the first to take place in Continental Europe—was held on August 28th and 29th in Ghent, Belgium.

The first session was opened by an address of welcome by President Schoentjes, of Ghent University, to which the president of the institute, Professor A. K. Huntington, replied.

The *second report of the Committee on the Corrosion of Metals* was presented by Dr. Bengough.

A summary of the second report is herewith given:

Details as to the nature of the practical problem have been ascertained from the inquiry forms returned to the institute. Important points brought out are:

1. The erratic nature of the trouble. Different users give as the normal life of a tube periods varying from 4 to 25 years.

2. The nature of the deterioration is in the great majority of cases dezincification, which results finally in a rotten and pitted tube. This type of corrosion is called "selective corrosion." Occasionally tubes fail by localized "complete corrosion," i.e., by the rapid removal of both Cu and Zn over certain areas.

3. It is not possible to correlate the failure of tubes with the presence, or nature, of the electric lighting system.

4. There is no obvious connection between any definite locality in a condenser and the frequency of dezincification.

The chemical and physical condition which exist in a condenser are considered; also the possible variations from point to point in the same condenser. It is the variations in these conditions which determine the locality at which corrosion commences. Engineers in charge of condenser plants are not usually in a position to study them, and consequently the information obtainable from them is of limited value.

There is an almost entire absence of experimental work showing how the speed and type of corrosion vary as the conditions vary. Consequently it has been considered advisable to carry out a detailed laboratory investigation into the matter.

I. *Laboratory investigation* on the standard tubes of the Corrosion Committee.

COMPOSITION OF STANDARD TUBES

	1. 70:30 Brass.	2. 70:28:2 (Pb). Special Brass.	3. 61:39 Muntz Metal.	4. 70:29:1 Admiralty Brass.
Copper	70.21	69.94	60.90	71.18
Zinc	29.17	27.60	38.21	27.28
Tin	.....	.....	.....	1.07
Lead	0.27	2.08	0.46	0.28
Iron	0.27	0.28	0.33	0.21
	99.92	99.90	99.90	100.02

Summary of results of experiments carried out at 20° C.:

(1) Corrosion at this temperature is always of the approximately complete type and is slow and uniform.

(2) Carbon (in the form of coal, graphite and coke), sand, copper and a number of other bodies have, *per se*, little or no effect on the speed or type of corrosion. They do not give rise to any appreciable electrochemical action.

(3) Certain basic salts of zinc and ferric oxide appear to have some slight accelerating effect, but it is too small to be practically important.

(4) An increase in the concentration of the sea-water increases the speed of corrosion; a decrease in concentration decreases it. The type of corrosion is unaffected (but see below).

(5) The order in which tubes resist loss of weight is as follows:
1. Muntz metal (loses least weight).
2. 70:28:2 alloy.
3. 70:30 brass.
4. Admiralty metal.

(6) An increase in the speed of the water increases the amount of corrosion.

(7) Jelly tests have given inconclusive results.

(8) "Selective corrosion" could not be obtained at 20° C. except by the employment of free acid, or by the use of diluted sea-water for very long periods of time.

(9) A detailed account is given of the nature of the reaction which takes place during the process of corrosion.

(10) No evidence is forthcoming that "flaws" and "spills" have any influence on corrosion at the ordinary temperature.

Most of the experiments carried out at 20° were repeated at 40°:

(1) Corrosion at this temperature is of a distinctly "selective" type, i.e., the zinc is removed from the metal in larger amount, proportionately, than the copper.

(2) This action is by no means uniform but begins at certain points and spreads outward. The causes which determine the distribution of these points is discussed in detail. The action is inherent in alloys of the types considered, given the presence of sea-water and suitable temperature conditions.

(3) The order of resistance to "selective corrosion" at this temperature is:
1. 70:28:2 alloy (most resistant).
2. Admiralty alloy.
3. 70:30.
4. Muntz metal.

(4) Sea-water diluted with its own volume of distilled water exerts a greater selective corrosion effect than ordinary sea-water. Concentrated sea-water stimulates complete corrosion, but represses selective corrosion.

(5) The influence of carbon particles, etc., was no greater than at the ordinary temperature.

(6) The presence of zinc oxychloride on a tube gives rise to severe dezincification.

Inquiries have shown that it is highly probable that temperatures of 50° C. and upward are frequently attained in condensers. Consequently a series of experiments at 50° were conducted, mainly on 70:30 brass and Admiralty metal.

Results of experiments at 50° C.:

(1) Corrosion is of the selective type, and is concentrated almost entirely on the zinc. Mere traces of copper only were removed from the tubes, except in the case of the Admiralty tube.

(2) The action is severely localized.

(3) The order of resistance to selective corrosion is:
1. Admiralty metal (most resistant).
2. Muntz metal.
3. 70:30 brass.

The last two tubes showed signs of dezincification in 7 days. No signs of dezincification could be detected in the Admiralty metal in 4 weeks.

(4) The total weight of metal lost is lower at 50° than at the ordinary temperature for equal lengths of time. If the water be aerated the weight lost is enormously increased, and is greater than at the ordinary temperature.

(5) The effect of particles is the same as at the lower temperatures.

(6) Diluted sea-water (as above) and concentrated sea-water act as at 40° C.

II. Full details of the work carried out with the experimental condenser plant are given, and a comparison is made between the conditions obtaining in it and in an ordinary marine condenser. Three tubes of each of the standard compositions have been withdrawn and examined. The tubes themselves and the scale have been subjected to detailed examination. All the tubes show signs of dezincification with the exception of one of the Admiralty tubes, and one of Muntz's special brass. The extent and distribution of the areas of dezincification are considered in the light of the laboratory work. The agreement in the results obtained by the two methods is very striking.

III. Some preliminary experiments on the nature and mode of action of electrochemical protection methods are described, and the important part played by calcium carbonate scale is emphasized.

Continuity versus Atomism—The Limitations of the Scope of Physics and Chemistry

Presidential Address Before the British Association for the Advancement of Science*

By Sir Oliver Lodge

Natura non vincitur nisi parendo.

Let us ask what, in the main, is the characteristic of the promising though perturbing period in which we live. Different persons would give different answers, but the answer I venture to give is—rapid progress, combined with fundamental scepticism. Rapid progress was not characteristic of the latter half of the nineteenth century—at least not in physics. Fine solid dynamical foundations were laid, and the edifice of knowledge was consolidated; but wholly fresh ground was not being opened up, and totally new buildings were not expected. With the realization of predicted ether waves in 1888, the discovery of X-rays in 1895, spontaneous radio-activity in 1896, and the isolation of the electron in 1898, expectation of further achievement became vivid; and novelties, experimental, theoretical and speculative, have been showered upon us ever since this century began. Of the progress I shall say little—there must always be some uncertainty as to which particular achievement permanently contributes to it; but I will speak about the fundamental scepticism. To exhibit my meaning very briefly, I may cite the kind of dominating controversies now extant, employing as far as possible only a single word in each case so as to emphasize the necessary brevity and insufficiency of the reference. In physiology the conflict ranges round *vitalism*. (My immediate predecessor dealt with the subject at Dundee.) In chemistry the debate concerns *atomic structure*. (My penultimate predecessor is well aware of pugnacity in that region.) In biology the dispute is on the laws of *inheritance*. (My successor is sure to deal with this subject; probably in a way not deficient in liveliness.) And besides these major controversies, debate is active in other sections: In education, *curricula* generally are being overhauled or fundamentally criticised, and revolutionary ideas are promulgated concerning the advantages of freedom for infants. In economic and political science, or sociology, what is there that is not under discussion? Not property alone, nor land alone, but everything—back to the garden of Eden and the inter-relations of men and women. Lastly, in the vast group of mathematical and physical sciences, "slurred over rather than summed up as section A," present-day scepticism concerns what, if I had to express it in one word, I should call *continuity*.

Still more fundamental and deep-rooted than any of these sectional debates, however, a critical examination of scientific foundations generally is going on; and a kind of philosophic scepticism is in the ascendant, resulting in a mistrust of purely intellectual processes and in a recognition of the limited scope of science. One thing is very notable, that it is closer and more exact knowledge that has led to the kind of scientific scepticism now referred to; and that the simple laws on which we used to be working were thus simple and discoverable because the full complexity of existence was tempered to our ken by the roughness of our means of observation. In most parts of physics simplicity has sooner or later to give place to complexity: though certainly I urge that the simple laws were true, and are still true, as far as they go, their inaccuracy being only detected by further real discovery. The reason they are departed from becomes known to us; the law is not really disobeyed, but is modified through the action of a known additional cause. Hence it is all in the direction of progress.

If we had to summarize the main trend of physical controversy at present, I feel inclined to urge that it largely turns on the question as to which way ultimate victory lies in the fight between continuity and discontinuity. On the surface of Nature at first we see discontinuity; objects detached and countable. Then we realize the air and other media, and so emphasize continuity and flowing quantities. Then we detect atoms and numerical properties, and discontinuity once more makes its appearance. Then we invent the ether and are impressed with continuity again. But this is not likely to be the end; and what the ultimate end will be, or whether there is an ultimate end, is a question difficult to answer. The modern tendency is to emphasize the discontinuous or atomic character of everything. Matter has long been atomic, in the same sense as anthropology is atomic; the unit of matter is the atom, as the unit of humanity is the individual. Certainly, however, there is an illusion of continuity. We recognize it in the case of water. It appears to be a continuous medium, and yet it is certainly molecular. It is made continuous again, in a sense, by the ether postulated in its pores; for the ether is essentially continuous. Though Osborne Reynolds, it is true, invented a discontinuous or granular ether, on the analogy of the sea shore. Electricity itself—i. e., electric charge—strangely enough has proved itself to be atomic. There is a natural unit of electric charge, as suspected by Faraday and Maxwell and named by Johnstone Stoney. Some of the electron's visible effects were studied by Crookes in a vacuum; and its weighing and measuring by J. J. Thomson were announced to the British Association meeting at Dover in 1899—a fitting prelude to the twentieth century. Even magnetism has been suspected of being atomic, and its hypothetical unit has been named in advance the magneton; but I confess that here I have not been shaken out of the conservative view. Discontinuity does not fail to exercise fascination even in pure mathematics. Curves are invented which have no tangent or differential coefficient, curves which consist of a succession of dots or of twists; and the theory of commensurable numbers seems to be exerting a dominance over philosophic mathematical thought as well as over physical problems. And not only these fairly accepted results are prominent, but some more difficult and unexpected theses in the same direction are being propounded, and the atomic character of energy is advocated. Then again radiation is showing signs of becoming atomic or discontinuous.

The forms of energy can be classified as either a translation, a rotation or a vibration of pieces of matter of different sizes, from stars and planets down to atoms and electrons; or else an etherial strain which in various different ways is manifested by the behavior of such masses of matter as appeal to our senses. Some of the facts responsible for the suggestion that energy is atomic seem to me to depend on the discontinuous nature of the structure of a material atom, and on the high velocity of its constituent particles. The apparently discontinuous emission of radiation is, I believe, due to features in the real discontinuity of matter. Disturbances inside an atom appear to be essentially catastrophic; a portion is liable to be ejected with violence. There appears to be a critical velocity below which ejection does not take place; and, when it does, there also occurs a sudden rearrangement of parts which is presumably responsible for some perceptible etherial radiation. Hence it is, I suppose, that radiation comes off in gushes or bursts; and hence it appears to consist of indivisible units. The occasional phenomenon of new stars, as compared with the steady orbital motion of the millions of recognized bodies, may be suggested as an astronomical analogue. The hypothesis of quanta was devised to reconcile the law that the energy of a group of colliding molecules must in the long run be equally shared among all their degrees of freedom, with the observed fact that the energy is really shared into only a small number of equal parts. For if vibration-possibilities have to be taken into account, the number of degrees of molecular freedom must be very large, and energy shared among them ought soon to be all frittered away; whereas it is not. Hence the idea is suggested that minor degrees of freedom are initially excluded from sharing the energy, because they cannot be supplied with less than one atom of it.

Now in all the debatable matters of which I have indicated possibilities I want to urge a conservative attitude. I accept the new experimental results on which some of these theories—such as the principle of relativity—are based, and am profoundly interested in them, but I do not feel that they are so revolu-

*Delivered at Birmingham on September 10, 1913.

tionary as their propounders think. I see a way to retain the old and yet embrace the new, and I urge moderation in the uprooting and removal of landmarks. And of these the chief is continuity. I cannot imagine the exertion of mechanical force across empty space, no matter how minute; a continuous medium seems to me essential. I cannot admit discontinuity in either space or time, nor can I imagine any sort of experiment which would justify such a hypothesis. For surely we must realize that we know nothing experimental of either space or time, we cannot modify them in any way. We make experiments on bodies, and only on bodies, using "body" as an exceedingly general term. We have no reason to postulate anything but continuity for space and time. We cut them up into conventional units for convenience sake, and those units we can count; but there is really nothing atomic or countable about the things themselves. We can count the rotations of the earth, or the revolutions of an electron, or the vibrations of a pendulum, or the waves of light. All these are concrete and tractable physical entities; but space and time are ultimate data, abstractions based on experience. We know them through motion, and through motion only, and motion is essentially continuous. Very well, then, what about the ether; is that in the same predicament? Is that an abstraction, or a mere convention, or is it a concrete physical entity on which we can experiment? Now it has to be freely admitted that it is exceedingly difficult to make experiments on the ether. It does not appeal to sense, and we know no means of getting hold of it. The one thing we know metrical about it is the velocity with which it can transmit transverse waves. That is clear and definite, and thereby to my judgment it proves itself a physical agent; not indeed tangible or sensible, but yet completely real. But it does elude our laboratory grasp. If we rapidly move matter through it, hoping to grip it and move it too, we fail: there is no mechanical connection. And even if we experiment on light we fail too. So long as transparent matter is moving relatively to us, light can be affected inside that matter; but when matter is relatively stationary to matter nothing observable takes place, however fast things may be moving, so long as they move together. Hence arises the idea that motion with respect to ether is meaningless: and the fact that only relative motion of pieces of matter with respect to each other has so far been observed is the foundation of the principle of relativity. It sounds simple enough as thus stated, but in its development it is an ingenious and complicated doctrine embodying surprising consequences which have been worked out by Professor Einstein and his disciples with consummate ingenuity.

Now the facts are that no motion with reference to the ether alone has ever yet been observed; there are always curious compensating effects which just cancel out the movement-terms and destroy or effectively mask any phenomena that might otherwise be expected. When matter moves past matter observation can be made; but, even so, no consequent locomotion of ether, outside the actually moving particles, can be detected. To detect motion through ether we must use an etherial process. We may use radiation, and try to compare the speeds of light along or across the motion; or we might try to measure the speed, first with the motion and then against it. But how are we to make the comparison? If the time of emission from a distant source is given by a distant clock, that clock must be observed through a telescope, that is, by a beam of light; which is plainly a compensating process. Or the light from a neighboring source can be sent back to us by a distant mirror; when again there will be compensation. Or the starting of light from a distant terrestrial source may be telegraphed to us, either with a wire or without; but it is the ether that conveys the message in either case, so again there will be compensation. Electricity, magnetism, and light, are all effects of the ether. Use cohesion, then; have a rod stretching from one place to another, and measure that. But cohesion is transmitted by the ether, too, if, as believed, it is the universal binding medium. Compensation is likely; compensation can, on the electrical theory of matter, be predicted. Use some action not dependent on ether, then. Very well, where shall we find it? If the electrical theory of matter be true, every material interaction will be electrical, i. e., etherial; and hence arises our difficulty. Every kind of force is transmitted by the ether, and hence so long as all our apparatus is traveling together at one and the same pace, we have no chance of detecting the motion. That is the strength of the principle of relativity.

The changes are not zero, but they cancel each other out of observation.

The electrical theory of matter is a positive achievement, and has positive results. By its aid we make experiments which throw light upon the relation between matter and the ether of space. The principle of relativity, which seeks to replace it, is a principle of negation, a negative proposition, a statement that observation of certain facts can never be made, a denial of any relation between matter and ether, a virtual denial that the ether exists. Whereas if we admit the real changes that go on by reason of rapid motion, a whole field is open for discovery; it is even possible to investigate the changes in shape of an electron —appallingly minute though it is—as it approaches the speed of light; and properties belonging to the ether of space, evasive though it be, cannot lag far behind. The ether of space is at least the great engine of continuity. It may be much more, for without it there could hardly be a material universe at all. Certainly, however, it is essential to continuity; it is the one all-permeating substance that binds the whole of the particles of matter together. It is the uniting and binding medium without which, if matter could exist at all, it could exist only as chaotic and isolated fragments; and it is the universal medium of communication between worlds and particles. And yet it is possible for people to deny its existence, because it is unrelated to any of our senses, except sight—and to that only in an indirect and not easily recognized fashion.

I hold that science is incompetent to make comprehensive denials, even about the ether, and that it goes wrong when it makes the attempt. Science should not deal in negations; it is strong in affirmations, but nothing based on abstraction ought to presume to deny outside its own region. It often happens that things abstracted from and ignored by one branch of science may be taken into consideration by another. Yet none of these ignored things should be denied. Denial is no more infallible than assertion.

All intellectual processes are based on abstraction. Hence it is that science has no authority in denials. To deny effectively needs much more comprehensive knowledge than to assert. And abstraction is essentially not comprehensive; one cannot have it both ways. Science employs the methods of abstraction and thereby makes its discoveries. The reason why some physiologists insist so strenuously on the validity and self-sufficiency of the laws of physics and chemistry, and resist the temptation to appeal to unknown causes—even though the guiding influence and spontaneity of living things are occasionally conspicuous as well as inexplicable—is that they are keen to do their proper work; and their proper work is to pursue the laws of ordinary physical energy into the intricacies of "colloidal electrolytic structures of great chemical complexity" and to study its behavior there. What we have clearly to grasp, on their testimony, is that for all the terrestrial manifestations of life the ordinary physical and chemical processes have to serve. There are not new laws for living matter and old laws for non-living, the laws are the same; or if ever they differ, the burden of proof rests on him who sustains the difference. The conservation of energy, the laws of chemical combination, the laws of electric currents, of radiation, etc., etc.—all the laws of chemistry and physics—may be applied without hesitation in the organic domain. Whether they are sufficient is open to question, but as far as they go they are necessary; and it is the business of the physiologist to seek out and demonstrate the action of those laws in every vital action.

I observe that by some critics I have been called a vitalist and in a sense I am; but I am not a vitalist if vitalism means an appeal to an undefined "vital force" (an objectionable term I have never thought of using) as against the laws of chemistry and physics. Those laws must be supplemented, but need by

no means be superseded. The business of science is to trace out their mode of action everywhere, as far and as fully as possible; and it is a true instinct which resents the mediæval practice of freely introducing spiritual and unknown causes into working science. In science an appeal to occult qualities must be illegitimate, and be a barrier to experiment and research generally; as, when anything is called an Act of God—and when no more is said. The occurrence is left unexplained. As an ultimate statement such a phrase may be not only true but universal in its application. But there are always proximate explanations which may be looked for and discovered with patience. So, lightning, earthquakes and other portents are reduced to natural causes. No ultimate explanation is ever attained by science: proximate explanations only. They are what it exists for; and it is the business of scientific men to seek them. So it is always in science, and its progress began when unknown causes were eliminated and treated as non-existent. Those causes, so far as they exist, must establish their footing by direct investigation and research; carried on in the first instance apart from the long recognized branches of science, until the time when they too have become sufficiently definite to be entitled to be called scientific. Outlandish territories may in time be incorporated as states, but they must make their claim good and become civilized first.

It is well for people to understand this definite limitation of scope quite clearly, else they wrest the splendid work of biologists to their own confusion—helped, it is true, by a few of the more robust or less responsible theorizers, among those who should be better informed and more carefully critical in their philosophizing utterances. But, as is well known, there are more than a few biologists who, when taking a broad survey of their subject, clearly perceive and teach that before all the actions of live things are fully explained some hitherto excluded causes must be postulated. Ever since the time of J. R. Mayer it has been becoming more and more certain that, as regards performance of work, a living thing obeys the laws of physics, like everything else; but undoubtedly it initiates processes and produces results that without it could not have occurred. The behavior of a ship firing shot and shell is explicable in terms of energy, but the discrimination which it exercises between friend and foe is not so explicable. There is plenty of physics and chemistry and mechanics about every vital action, but for a complete understanding of it something beyond physics and chemistry is needed. And life introduces an incalculable element. The vagaries of a fire or a cyclone could all be predicted by Laplace's calculator, given the initial positions, velocities, and the law of acceleration of the molecules; but no mathematician could calculate the orbit of a common house-fly. A physicist into whose galvanometer a spider had crept would be liable to get phenomena of a kind quite inexplicable, until he discovered the supernatural—*i.e.*, literally super-physical cause. I will risk the assertion that life introduces something incalculable and purposeful amid the laws of physics; it thus distinctly supplements those laws, though it leaves them otherwise precisely as they were and obeys them all.

What appears to be quite certain is that there can be no terrestrial manifestation of life without matter. Hence naturally they say, or they approve such sayings as, "I discern in matter the promise and potency of all forms of life." Of all terrestrial manifestations of life, certainly. How else could it manifest itself save through matter? "I detect nothing in the organism but the laws of chemistry and physics," it is said. Very well; naturally enough. That is what they are after; they are studying the physical and chemical aspects or manifestations of life. But life itself—life and mind and consciousness—they are not studying, and they exclude them from their purview. Matter is what appeals to our senses here and now; materialism is appropriate to the material world; and not as a philosophy but as a working creed, as a proximate and immediate formula for guiding research. Everything beyond that belongs to another region, and must be reached by other methods. To explain the psychical in terms of physics and chemistry is simply impossible; hence there is a tendency to deny its existence, save as an epiphenomenon. But all such philosophizing is unjustified, and is really bad metaphysics.

But although life and mind may be excluded from physiology they are not excluded from science. Of course not. It is not reasonable to say that things necessarily elude investigation merely because we do not knock up against them. Yet the mistake is sometimes made. The ether makes no appeal to sense, therefore, some are beginning to say that it does not exist. Mind is occasionally put into the same predicament. Life is not detected in the laboratory, save in its physical and chemical manifestations; but we may have to admit that it guides processes nevertheless. It may be called a catalytic agent. To understand the action of life itself, the simplest plan is not to think of a microscopic organism, or any unfamiliar animal, but to make use of our own experience as living beings. Any positive instance serves to stem a comprehensive denial; and if the reality of mind and guidance and plan is denied because they make no appeal to sense, then think how the world would appear to an observer to whom the existence of men was unknown and undiscoverable, while yet all the laws and activities of Nature went on as they do now. Suppose, then, that *man* made no appeal to the senses of an observer of this planet. Suppose an outside observer could see all the events occurring in the world, save only that he could not see animals or men. He would describe what he saw much as we have to describe the activities initiated by life. If he looked at the Firth of Forth, for instance, he would see piers arising in the water, beginning to sprout, reaching across in strange manner till they actually join or are joined by pieces attracted up from below to complete the circuit (a solid circuit round the current). He would see a sort of bridge or filament thus constructed, from one shore to the other, and across this bridge insect-like things crawling and returning for no very obvious reason. If told that an engineer, a designer in London, called Benjamin Baker, had anything to do with it the idea would be preposterous. One conclusive argument is final against such a superstitious hypothesis—he is not there, and a thing plainly cannot act where it is not. But although we, with our greater advantages, perceive that the right solution for such an observer would be the recognition of some unknown agency or agent, it must be admitted that an explanation in terms of a vague entity called vital force would be useless, and might be so worded as to be misleading; whereas a statement in terms of mechanics and physics could be clear and definite and true as far as it went, though it must necessarily be incomplete.

And note that what we observe, in such understood cases, is an *interaction* of mind and matter; not parallelism nor epiphenomenalism, nor anything strained or difficult; but a straightforward utilization of the properties of matter and energy for purposes conceived in the mind and executed by muscles guided by acts of will. But, it will be said, this is unfair, for we *know* that there is design in the Forth Bridge or the Nile Dam, we have seen the plans and understand the agencies at work; we know that it was conceived and guided by life and mind, it is unfair to quote this as though it could simulate an automatic process. Not at all, say the extreme school of biologists whom I am criticizing, or ought to say if they were consistent, there is nothing but chemistry and physics at work anywhere; and the mental activity apparently demonstrated by those structures is only an illusion, an epiphenomenon; the laws of chemistry and physics are supreme, and they are sufficient to account for everything! Well, they account for things up to a point; they account in part for the color of a sunset, for the majesty of a mountain peak, for the glory of animate existence; but do they account for everything completely? Do they account for our own feeling of joy and exaltation, for our sense of beauty, for the manifest beauty existing throughout Nature? Do not these things suggest something higher and nobler and more joyous, something for the sake of which all the struggle for existence goes on?

Surely there must be a deeper meaning involved in natural objects. Orthodox explanations are only partial, though true as far as they go. When we examine each parti-colored pinnule

in a peacock's tail, or hair in a zebra's hide, and realize that the varying shades on each are so placed as to contribute to the general design and pattern, it becomes exceedingly difficult to explain how this organized co-operation of parts, this harmonious distribution of pigment cells, has come about on merely mechanical principles. It would be as easy to explain the sprouting of the cantilevers of the Forth Bridge from its piers, or the flocking of the stones of the Nile Dam by chemiotaxis. Flowers attract insects for fertilization, and fruit tempts animals to eat it in order to carry seeds; but these explanations cannot be final. We have still to explain the insects. So much beauty cannot be necessary merely to attract their attention. We have further to explain this competitive striving towards life. Why do things struggle to exist? Surely the effort must have some significance, the development some aim. We thus reach the problem of existence itself and the meaning of evolution. The mechanism whereby existence entrenches itself is manifest, or at least has been to a large extent discovered. Natural selection is a vera causa, so far as it goes; but if so much beauty is necessary for insects, what about the beauty of a landscape or of clouds? What utilitarian object do those subserve? Beauty in general is not taken into account by science. Very well, that may be all right, but it exists nevertheless. It is not my function to discuss it. No; but it is my function to remind you and myself that our studies do not exhaust the universe, and that if we dogmatize in a negative direction, and say that we can reduce everything to physics and chemistry, we gibbet ourselves as ludicrously narrow pedants, and are falling far short of the richness and fullness of our human birthright.

But if we have learned from science that evolution is real, we have learned a great deal. Surely evolution is not an illusion, surely the universe progresses in time. Time and space and matter are abstractions, but are none the less real; they are data given by experience, and time is the keystone of evolution. We abstract from living, moving reality a certain static aspect, and we call it matter; we abstract the element of progressiveness, and we call it time. When these two abstractions combine, co-operate, interact, we get reality again. It is like Poynting's theorem. The only way to refute or confuse the theory of evolution is to introduce the subjectivity of time. That theory involves the reality of time, and it is in this sense that Prof. Bergson uses the great phrase "creative evolution."

I see the whole of material existence as a steady passage from past to future, only the single instant which we call the present being actual. The past is not non-existent, however, it is stored in our memories, there is a record of it in matter, and the present is based upon it; the future is the outcome of the present, and is the product of evolution. Where inorganic matter alone is concerned, there everything is determined. Wherever full consciousness has entered new powers arise, and the faculties and desires of the conscious parts of the scheme have an effect upon the whole. It is not guided from outside, but from within; and the guiding power is immanent at every instant. Of this guiding power we are a small but not wholly insignificant portion. That evolutionary progress is real is a doctrine of profound significance, and our efforts at social betterment are justified because we are a part of the scheme, a part that has become conscious, a part that realizes, dimly at any rate, what it is doing and what it is aiming at. Planning and aiming are, therefore, not absent from the whole, for we are part of the whole, and are conscious of them in ourselves. Either we are immortal beings or we are not. We may not know our destiny, but we must have a destiny of some sort. Those who make denials are just as likely to be wrong as those who make assertions; in fact, denials are assertions thrown into negative form. Scientific men are looked up to as authorities and should be careful not to mislead. Science may not be able to reveal human destiny, but it certainly should not obscure it. Things are as they are whether we find them out or not, and if we make rash and false statements posterity will detect us—if posterity ever troubles its head about us. I am one of those who think that the methods of science are not so limited in their scope as has been thought; that they can be applied much more widely, and that the psychic region can be studied and brought under law, too. Allow us, anyhow, to make the attempt; give us a fair field. Let those who prefer the materialistic hypothesis by all means develop their thesis as far as they can; but let us try what we can do in the psychical region, and see which wins. Our methods are really the same as theirs—the subject-matter differs. Neither should abuse the other for making the attempt.

Whether such things as intuition and revelation ever occur is an open question. There are some who have reason to say that they do. They are at any rate not to be denied off-hand. In fact, it is always extremely difficult to deny *anything* of a general character, since evidence in its favor may be only hidden and not forthcoming, especially not forthcoming at any particular age of the world's history, or at any particular stage of individual mental development. Mysticism must have its place, though its relation to science has, so far, not been found. They have appeared disparate and disconnected, but there need be no hostility between them. Every kind of reality must be ascertained and dealt with by proper methods. If the voices of Socrates and of Joan of Arc represent real psychical experiences, they must belong to the intelligible universe.

Although I am speaking ex cathedra, as one of the representatives of orthodox science, I will not shrink from a personal note summarizing the result on my own mind of 30 years' experience of psychical research, begun without predilection—indeed, with the usual hostile prejudice. This is not the place to enter into details or to discuss facts scorned by orthodox science, but I cannot help remembering that an utterance from this chair is no ephemeral production, for it remains to be criticized by generations yet unborn, whose knowledge must inevitably be fuller and wider than our own. Your president, therefore, should not be completely bound by the shackles of present-day orthodoxy, nor limited to beliefs fashionable at the time. In justice to myself and my co-workers I must risk annoying my present hearers, not only by leaving on record our conviction that occurrences now regarded as occult can be examined and reduced to order by the methods of science carefully and persistently applied, but by going further and saying with the utmost brevity, that already the facts so examined have convinced me that memory and affection are not limited to that association with matter by which alone they can manifest themselves here and now, and that personality persists beyond bodily death. The evidence to my mind goes to prove that discarnate intelligence, under certain conditions, may interact with us on the material side, thus indirectly coming within our scientific ken; and that gradually we may hope to attain some understanding of the nature of a larger, perhaps etherial, existence, and of the conditions regulating intercourse across the chasm. A body of responsible investigators has even now landed on the treacherous but promising shores of a new continent.

Many scientific men still feel in pugnacious mood towards theology because of the exaggerated dogmatism which our predecessors encountered and overcame in the past. They had to struggle for freedom to find truth in their own way; but the struggle was a miserable necessity, and has left some evil effects. And one of them is this lack of sympathy, this occasional hostility, to other more spiritual forms of truth. We cannot really and seriously suppose that truth began to arrive on this planet a few centuries ago. The pre-scientific insight of genius—of poets and prophets and saints—was of supreme value, and the access of those inspired seers to the heart of the universe was profound. But the camp followers, the scribes and pharisees, by whatever name they may be called, had no such insight, only a vicious or a foolish obstinacy; and the prophets of a new era were stoned. Now at last we of the new era have been victorious; we inherit the fruits of the age-long conflict, and the stones are in our hands. Let us not fall into the old mistake of thinking that ours is the only way of exploring the multifarious depths of the universe, and that all others are worthless and mistaken. The universe is a larger thing than we have any conception of, and no one method of search will exhaust it

treasures. Men and brethren, we are trustees of the truth of the physical universe as scientifically explored, let us be faithful to our trust. Genuine religion has its roots deep down in the heart of humanity and in the reality of things. It is not surprising that by our methods we fail to grasp it; the actions of the Deity make no appeal to any special sense, only a universal appeal, and our methods are, as we know, incompetent to detect complete uniformity. There is a principle of relativity here, and unless we encounter flaw or jar or change nothing in us responds; we are deaf and blind, therefore, to the immanent grandeur around us, unless we have insight enough to appreciate the whole, and to recognize in the woven fabric of existence flowing steadily from the loom in an infinite progress towards perfection, the ever-growing garment of a transcendent God.

Winona Stamp-Mill.*

By R. B. Seeber

From October, 1906, to November, 1907, the Winona mine shipped rock from one shaft to the Adventure stamp-mill. This rock showed a total copper content of about 20 lb. per ton stamped. A large part of the contained copper was fine or flaky, making extraction very difficult. Only a trifle over 13 lb. per ton stamped was recovered during this period. With such a low grade ore, it was obviously necessary to practice every economy if a profit was to be obtained. The transportation cost per ton stamped was 17.5 cents during this period, or considerably over 1 cent per pound on the copper obtained. If a stamp-mill were to be built on the mine location without otherwise increasing operating expenses evidently a large proportion of this expense might be eliminated.

There are two principal reasons for the location of stamp-mills away from the mine, namely: To provide ample water for washing and to provide room for disposal of tailings. To meet the water requirement, with the mill on the mine at Winona, a dam across the Sleeping River was necessary. For a two-head mill it would also be necessary to use at least 50 per cent of the water over and over, as the stream flow is only about 3,000,000 gallons per 24 hours.

To meet the sand-room requirements, some dewatering device and sand-stacking equipment would be necessary.

After considerable study it was decided that these requirements could be met without prohibitive first cost or undue operating expense and work on a two-head mill was begun May 22, 1909.

Selection of Mill Site

The location chosen was a hillside between No. 4 shaft, Winona, and No. 1 shaft, King Philip. On the line of the stamp-heads pipes were driven which, when stopped, indicated a layer of hard material at a depth of 40 feet below the intended plane of the stamp base. On this material the concrete foundation of each stamp-head was expected to rest. This foundation is cylindrical. A steel caisson, 15 ft. in diameter, was weighted with a concrete ring 3 ft. thick and sunk as a drop shaft. When the expected layer of hard material was reached it was found to be thin and to be underlain by at least 80 ft. of sand, some of which was wet. Sinking was therefore continued until a sufficiently hard layer of material was encountered at about 55 ft. below the intended plane of the stamp base. The concrete ring was blocked up and a mushroom foot of concrete built in. The top 7 ft. of the caisson and concrete foundation was made 22 ft. in diameter in order to accommodate the 16-ft. square base for the head casting. The castings below the rock (from mortar down) weigh about 80 tons. The total weight of the stamp is about 115 tons. When sinking the 15-ft. caisson it was found that 43 ft. of concrete ring would be held up by the friction of the sand against the outer surface of the steel shell. Including the 7 ft. of 22-ft. ring, this skin friction would care for at least 400 tons of total weight of about 1050 tons to be supported, (935 tons foundation; 115 tons stamp), leaving 650 tons to be supported on the sand under the 20-ft. ring, 203 square ft. and the 20-ft. diameter base (314 square ft.) or a load of a little over 1.25 tons per square ft. on the total area of 517 square ft.

Velocity cards of the stamps show a blow of from 24 to 33 ft. tons. This is partly absorbed in crushing rock. As a foundation to assist in absorbing the balance there are supplied 80 tons of cast iron and 930 tons of concrete. After two years of use, no settling of foundations is in evidence and I am inclined to the belief that the foundations are much larger than is necessary.

Foundation walls were all of concrete, of a 1:3:5 mixture; all walls stand on dry, hard sand. The bin foundation walls were separated from the stamp foundations by tarred paper in order that any settling of the latter need not disturb the building foundations. The octagonal foundations for the rock bins were tied together, to a certain extent, by old wire cable.

Under the slime department floors eight tanks were built for settling the slimes and decanting the dirty water, to be reused in the mill. These tanks are 46 ft. long by 24 ft. wide, and 14 ft. deep. The walls are 14 to 24 in. thick and are reinforced by vertical iron rods ¾ in. in diameter, bent at the bottoms to make the joint into the floor.

It was very difficult to place and dump the concrete about

FIG. 1.—WINONA STAMP MILL

these rods, but the walls when completed showed but a few small leaks which were easily stopped and give no trouble in operation.

The steel structure was made and erected by the Wisconsin Bridge & Iron Company. In general arrangement, it is the same as the usual copper country mill. Circular steel rock bins are used, two supplying each head, the openings being run together high up the sides thus allowing a large proportion of the contents to run out freely. The storage capacity of four bins is about 525 tons, or sufficient to last over night.

Instead of a trolley beam over the stamps a light crane beam was installed. This has proved very convenient in operating as well as during erection. This crane also handles all roll parts, etc.

Roof Construction

Over the slime department, at right angles to the line of the stamps, it was impossible to get in the usual step form of roof in a manner to allow sufficient light. Skylights of wire-glass were therefore tried and have proved satisfactory although snow sometimes accumulates over them. The roof is the usual form of matched flooring but is covered with Brooks' 4-ply asbestos roofing, in sheets about 3 ft. by 7 ft. During the first winter much trouble was experienced with ice on the eaves. As snow melts over the main body of the warm roofs the water runs down until it strikes the eaves, which are cold. It there freezes and makes a dam of ice which backs the water up until it runs through some opening or freezes and adds to the ice already formed. Immense icicles were sometimes formed

*Abstract of a paper read at the Lake Superior Mining Institute, Aug. 26-30, 1913.

down the sides of the building to the ground. This trouble has been entirely overcome by building wooden dams just back of the line of the eaves on each step of roof. These dams slope to holes in the roof leading to a piping system inside the mill which carries off the water. The warm air from the interior keeps these pipes free from ice, and as fast as snow melts it runs off the roof. This scheme was copied from a similar one at the Calumet & Hecla mills but I have seen no description of it in print.

The main slime department floor over the top of the settling tanks is made of concrete reinforced with triangle-mesh wire. The outside walls of the building are formed by a thick coat of cement plaster on a chicken-wire reinforcement. The inside face of the wall is made in the same manner, which leaves a good air space in the wall. The mortar is made of cement, sand, and a little lime.

Disposition of Tailings

Rough tailings from the tails of the jigs are de-watered by a large wheel and fed to a cross conveyor which discharges over the main conveyor running the long way of the mill. This main conveyor operates within a steel bridge supported on three steel towers and, when dumping, reaches a maximum height of 84 ft. above the track level at the bottom of the mill and 123 ft. above the ground. The conveyor is of the usual Robins type with troughing idlers on a 30-degree angle. The belt is balata, 20 in. wide. It has been in operation since March, 1911, and apparently has a long time yet to run before needing replacement. The conveyor is inclined 1¾ in. per ft., or 8 deg. 18 min.

A slime launder of steel extends 1200 ft. below the mill. This has a semi-circular bottom, with straight sides. We are now, (March, 1913) putting in the first steel liners. The wear is only around the rivet heads where eddy-currents are set up. This launder slopes ¼ on an inch to the foot and carries all the slime material. It empties into a ravine which joins the main river at a distance of about a mile and a half from the mill but on land belonging to the Winona Copper Company. If necessary, at any time in the future, a dam could be built across the river at this point and water pumped back to the mill.

A circular steel bin that can hold about four cars of coarse sand is situated over the track to the mineral bin. This can be filled from a separate belt conveyor parallel to the main conveyor and, during the summer months, much of the coarse sand is sold for concrete work and for railroad ballast.

The main trestle to the rock bins is used as a coal trestle. The coal plat is 30 ft. below the base of the rail. The floor is of concrete, about 4 in. thick. The usual coal adit under the main trestle is also made from concrete. The storage capacity of the plat is about 6000 tons. The trestle is of steel. The coal adit enters the boiler house at the same elevation as the ash adit in front of the boilers. An electric elevator elevates the car with ashes to an ash trestle and the car with coal to a tresle 8 ft. above the floor and running parallel to the boiler front. The coal supply is dumped on the floor and the boilers are fired by hand. The stack is of steel, brick lined. It is 150 ft. high and 6 ft. in diameter. The boilers were made by Parker, of Philadelphia. They are three in number, each 268 horsepower and are set in brick. They are equipped with Andrews' shaking grates, draft regulators and feedwater regulators.

The assay office is near the railroad at the bottom of the mill. It is supplied with the usual equipment for both fire and electrolytic assaying. A motor generator supplies the storage batteries for electrolytic work. A Tirrill gasoline gas plant supplies the gas.

Construction of Dam

A dam for the main water supply of the mill is situated on the Sleeping River, about 3900 ft. from the mill. It is 440 ft. long and 27 ft. high. The width of the bank on top is 15 ft. The slope on the water side is 2 to 1 and on the down stream side is 2½ to 1. The spillway is 7 ft. wide and 8 ft. deep from the top of the concrete core wall. With all flash boards out of the spillway, the storage capacity of the dam is about 77,000,000 gallons. Its volume is just about doubled by 5 ft. of flash boards. The core wall of the dam is concrete, 12 in. thick at the top and as much as 6 ft. at the very bottom. The sand fill was made mostly by the hydraulic process, a pump on the stream supplying water for washing sand from the banks. Both slopes are riprapped with coarse rock from the mine. A sheet steel intake 4 ft. square with a screen underneath, was first used but quickly became clogged with leaves, etc. A straight pipe 18 in. in diameter, the periphery filled with 1½-in. holes and rising above the highwater level, was then tried. This has given no trouble beyond catching in the ice once as the water level dropped.

The main pump is situated in a compressor house on the river bank. The pump was made by the Laidlaw-Dunn-Gordon Company. It has water cylinders 11¼ x 24 in. and steam cylinders 12 and 25 by 24 in. stroke. The cooling water for condensation is furnished by the main suction of the pump. Water enters the suction under a head of 5 lb. Steam pressure is 200 lb. The pumping capacity, at 67½ revolutions per minute, is 4,000,000 gallons per 24 hours.

The pipe line connecting the pump to the surge tank on top of the stamp-mill is spiral-riveted double galvanized pipe, with bolted points and rubber gaskets. The pressure at the pump is 86 pounds per square inch with the pump running. We have ruptured several lengths of this pipe, the rupture cutting clear across the steel. This was probably due to flaws in the steel. The joints have not given trouble. The pipe is 14 in. in diameter and 3900 ft. long. The surge tank on top of the mill supplies pressure for fire lines. All piping for the mill is direct from this tank.

Simple and Compound Steam Stamps

The steam stamps were made by the Allis-Chalmers Company. One is a simple stamp with a cylinder 24 in. diameter by 25 in. stroke and the other a compound with cylinders 16 and 32 in. diameter by 25 in. stroke. Both stamps have piston valves and only two eccentrics. The high-pressure cylinder of the compound stamp is on top and is removed bodily by the crane, if necessary to inspect the low-pressure cylinder or the piston. The rolls are of the rigid type and were made by the Allis-Chalmers Company. Four trommels are used instead of two.

The jigs are of the Woodbury system. One bull jig is used for the oversize and four four-compartment sets per head for the material through the trommels. Owing to the small percentage of No. 1 copper (medium-sized pieces) contained in the Winona rock, these jigs do not seem well adapted to the purpose. They do make an excellent separation of slimes for table treatment and provide a middling feed for regrinding mills. The jigs are supported on iron brackets instead of the usual timber supports. This makes it easier to get under the machines for adjustment and repairs and for washing floors.

De-watering Wheel

The principal machine developed for the operation of this mill is the de-watering wheel. As it is necessary to re-use the water, the tailings had to be separated from it. The water carrying the tails of the jigs is comparatively free from slime so that it is kept separate as "clear water" and re-used as wash water. The first de-watering device tried consisted of a screen tacked on a cylindrical frame which revolved slowly. The tails were drawn through spigots onto the outside of this screen the water falling through and the coarse material going over with the screen on to the cross conveyor belt. This scheme was not satisfactory as the spigots required a great deal of attention, having a tendency to either clog or to run water as the feed varied. An 8-ft. wheel along the lines of the present wheel was then developed. This worked well but the 12-ft. diameter wheel now used gives more room for launders, etc., and takes care of two heads. As shown by the drawing, Fig. 2, the de-watering wheel consists of a sheet steel water-tight wheel with radial partitions along the periphery forming pockets in which the sand is caught and lifted out of the water and

discharged at the top of the wheel over an apron on to the belt conveyor. The sand is run from settling tanks through spigots into the bottom of the wheel.

The water overflowing from the wheel is carried to the settling tanks and re-used.

The sand conveyor problem gave some little trouble before it was satisfactorily solved. The first cross conveyor used delivered sand to a bucket elevator which persisted in clogging and otherwise causing trouble. This was removed and the cross conveyor curved up to deliver directly to the main conveyor. Some trouble was experienced with the belts getting out of line but this was gradually eliminated until the sand

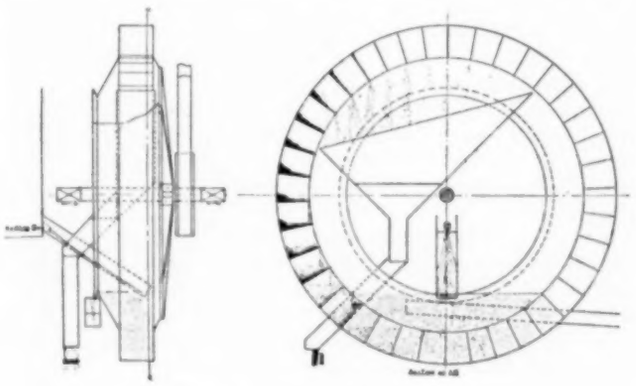


FIG. 2.—DEWATERING WHEEL

conveyor equipment now has no special attendant. As a large pile of sand was piled up around the last tower of the sand conveyor the ground began to bulge up around the edge of the pile. Settlement of the outside tower came with this movement and finally caused shearing of rivets on the upper side of the conveyor bridge over the middle tower. These rivets were then cut out and bolts in slots substituted. A pin joint was placed in the bottom of the truss. This allowed for about 2 ft. of settlement in the outer tower. The settling continued until it became necessary to cut the conveyor house free from the outside tower. The conveyor bridge is now supported at the far end on blocking and jacks from the steel of the tower embedded in the sandpile. If settlement continues, the conveyor bridge will be jacked up to keep pace. As the sand accumulates the conveyor will be extended and supported on the sand.

As regrinding increases the amount of coarse sand to be stacked will decrease.

Regrinding with Hardinge Mills

Milling was started with one 8 x 30 in. Hardinge conical mill. During 1912 two more were installed, one a 6-ft. by 60-in. straight face and the other an 8-ft. by 18-in. straight face. For one period of January, 1912, no mill was at work. For most of the first six months two mills were in operation and for the last six months three mills were in operation. During the year about 36,000 tons of material was reground. This figure is of course not exact but from several tests and records of time, etc., I feel sure that it is very nearly right. From the reground material 215,248 lb. of refined copper was produced. The grade of this mineral will average better than 50 per cent. The total cost of regrinding during the year was $9,697.09 or 26.93 cents per ton reground, and 4.5 cents per pound of copper recovered. With electricity costing 1.2 cents per kw-hour, the power cost was $7,501.97 of the above total amount. Labor was $402.85 and supplies cost $1,792.27. Of the supplies, $1,235.80 was for 172,030 pounds of French pebbles and $280.68 for 19,342 pounds of silex lining. The balance was for oil and supplies incidental to repairs. The pebble loss figures nearly 5 lb. per ton reground as it includes the initial charge for two new mills. The pebble loss is now running a trifle under 4 lb. per ton reground, which is higher than usual in this district on account of the hardness of the rock.

Costs of Grinding 36,000 Tons

	Total	Per Ton Reground.	Per Cent.	Units per Ton Ground.
Power 1.2c, per kw. hr.	$7,501.97	20.84c.	77.36	17.415 kw. hrs.
Labor	402.85	1.12	4.15	
Supplies—				
.7184c. per lb. pebbles	1,235.80	3.43	12.74	4.78 lb. pebbles
1.4512c. per lb. lining	280.69	.77	2.90	.537 lb. lining
Incidentals	275.78	.77	2.85	
	$9,697.09	26.93c.	100.00	

The 8-ft. diameter by 30-in. straight face mill has proved the most economical in power cost per ton ground and also has the largest capacity of any we have tried. We are now installing three more 8-ft. mills which have a 36-in. straight face and we expect still greater capacity. These mills have Falk's cut herringbone gears and there is only one speed reduction, which will materially reduce the power cost. The first mill installed has a silex lining but the subsequent mills are lined on the straight face with pebbles set in grooves in steel plates. The conical faces are lined with silex blocks. Steel-pebble linings have proved very satisfactory. A mill is out of service at least four days to replace silex lining as the cement must be allowed to set. With a steel-pebble lining, the mill can go into service again as soon as new plates are placed, a matter of hours only. So far, our experience shows that the steel-pebble linings are cheapest. All our new mills will be equipped with the steel-pebble linings on the cones as well as the straight faces.

The mill is lighted at night, principally, by 100 candlepower series Tungsten incandescent lamps on a 6.6 ampere constant current. These have been found satisfactory, the life of the lamps running above 2000 hours.

The Winona stamp-mill was built on the mine to reduce operating expenses per ton by reducing transportation charges. Seventeen and one-half cents per ton was cut out of the transportation charge and the following items were added:

Stacking sand .....1.2c. per ton stamped
Transportation on the mine.....3.6c. per ton stamped

This still leaves an important net saving due to location of mill on the mine. The unit costs given are necessarily high

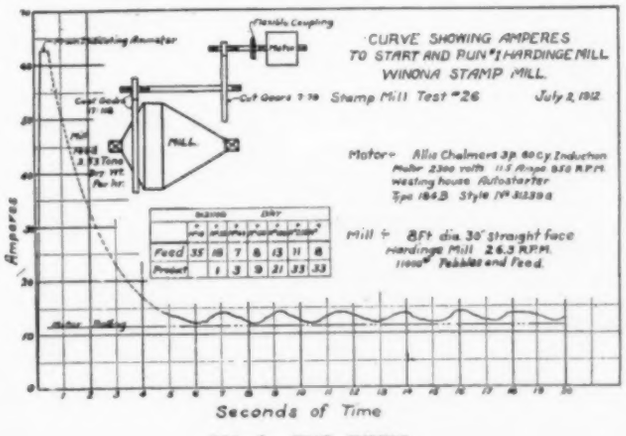

CURVE SHOWING AMPERES
TO START AND RUN #1 HARDINGE MILL
WINONA STAMP MILL.
Stamp Mill Test #26
July 2, 1912
Flexible Coupling
Cut Gears 7.79
MILL
Motor- Allis Chalmers 3p 60 cy Induction
Motor 2300 volts 11.5 Amps 850 R.P.M.
Westing house Autostarter
Type 184.B Style No 813390
Mill - 8Ft dia 30" Straight face
Hardinge Mill 26.3 R.P.M.
1100# Pebbles and Feed.
Feed 35 18 7 6 13 11 8
Present 1 3 9 21 33 33
Amperes
Seconds of Time

FIG. 3.—TEST CURVES

due to the small tonnage handled, namely, 181,184 tons for the year 1912. The detail of these costs follows:

Cost of belt and conveyor idlers, about $4,000 erected; life 40 months; cost per month	$100.00
Power at the rate of 8 kw. at 1.2c. per kw-hour	60.00
Attendance	10.00
Oils, etc.	10.00
	$180.00

Or 1.2 cents per ton on 15,000 tons stamped. These will of course be reduced materially with increased tonnage handled. Of the power used, at least two-thirds is in friction.

In addition, the following interest and depreciation charges might be listed against this operation:

Cost of conveyor bridge and towers, fully equipped with belt and machinery	$12,000.00

Interest at 6 per cent.....	720.00
5 per cent depreciation on $8,000 of this amount....	400.00

The depreciation of the other $4,000 is already accounted for in the working cost.

Pumping costs should not be increased over similar costs with a stamp-mill on Lake Superior as while the water rehandled is pumped with less efficient machinery the head against which it is pumped is very materially reduced. The pumping cost taken from our cost sheet for the year 1912 is 2.3 cents per ton stamped. This is materially higher than the usual figure on Lake Superior, owing, principally, to the smaller tonnage stamped.

There is undoubtedly considerable gained by the concentration of all operations at the mine. Some of this gain cannot be expressed in cents per ton. During part of the month of March, 1913, railroad service in Houghton county was very much hindered by heavy storms. Several of the mines were shut down temporarily and freight train service, at least, was cancelled for days at a time. Neither the Winona mine nor the mill was delayed on this account as our tracks are comparatively short and easily kept clear of snow.

Quantitative Spectrum Analysis

By G. A. Shook

II Spectrophotometers

Whenever white light, such as sunlight or the light from any incandescent solid, is passed through a prism, it is broken up or dispersed into a continuous band of colors which is known as the *spectrum* of white light.

The spectrum of a gas consists of bright lines which are more or less well defined; for example, when a salt of sodium is vaporized it produces a yellow flame and if this flame is examined by means of a small spectroscope its spectrum is observed to consist of one bright yellow line.

If a colored solution, say copper sulphate, is placed before the slit of the spectroscope we obtain the *absorption spectrum* of copper sulphate. The solution does not transmit simply one blue line, but to some degree all the colors, the blue region, of course, being the brightest. The intensity diminishes rapidly in the orange and yellow region and is relatively weak in the red region.

A cobalt solution, on the other hand, gives an absorption spectrum which is more intense in the red than in the blue.

In the case of most organic compounds, however, the intensity does not vary continuously from color to color, but the bands are more numerous and generally very much narrower than the bands observed in the spectrum of a simple solution like copper sulphate.

In the first article of this series, published in the September issue of this journal, it is shown that the concentration of a solution is directly proportional to the logarithm of that fraction of light transmitted by unit layer of the solution, that is

$$\log (I'/I) = kc$$

or

$$c = -\log (I'/I) = A\,e \qquad (1)$$

where I is the intensity of the incident light and I' the intensity of the transmitted light.

e is known as the *extinction coefficient* and A the *absorption ratio*. The concentration c will be expressed in per cent in all the calculations that follow. A 10 per cent solution here means that 10 grams of solute are dissolved in 100 c.c. of solvent.

Any notation may, of course, be used so long as one is consistent.

In many of the best instruments the intensity is controlled by means of a slit and the screw head which actuates the slit is divided into 100 divisions. When the head is turned to the 100 mark the slit is opened 1 mm. It will, therefore, be found convenient, in some cases, to express the fraction of the light transmitted, I'/I, in per cent.

From the theory of logarithms we have the following theorems:

$$\log A/B = \log A + \log B,$$
$$\log (A/B) = \log A - \log B$$

and

$$-\log (A/B) = \log B - \log A.$$

We may now write

$$e = -\log (I'/I) = \log I - \log I'.$$

Suppose, for example, that 20 per cent of the incident light is transmitted through a unit layer of a solution, then

$$e = \log 20/100 = \log 100 - \log 20 = 2 - 1.301 = 0.699.$$

Therefore, whenever (I'/I) is expressed in per cent

$$e = 2 - \log I' \qquad (2)$$

and

$$c = A\,e = A\,(2 - \log I') \qquad (3)$$

These relations are only strictly true for homogeneous light, *i.e.*, light of one color, so that in accurate work it is best to use a *spectro-colorimeter* or a *spectrophotometer* for the optical determination of concentrations.

In the spectro-colorimeter the light from the two containing vessels is rendered monochromatic either by means of a prism system or a number of monochromatic glasses. The latter method allows more light to be transmitted, but is not so accurate as the former.

In the type of spectrophotometer which is especially adapted for the determination of concentrations, the light from a suitable source of illumination such as a frosted globe, glow-lamp, or an Auer burner, is divided into two beams and one of these passes through a layer of the solution to be investigated. The transmitted beam and the uninterrupted beam then traverse a prism system which causes each to be drawn out into a spectrum or a band of colors and thence they are transmitted through some sort of a photometric screen to the eye.

By means of a diaphragm a narrow region, only, of the spectrum is transmitted to the eye. Somewhere in the path of the two beams is inserted a device for bringing them to equal intensity and this device gives us a measure of the relative intensity of the two. The ratio of the intensity of the transmitted beam to the intensity of the uninterrupted beam gives us at once the extinction coefficient of the solution in question for the particular color or wave-length of light employed. The commercial instruments accomplish these various ends in different ways and we shall therefore consider some of the typical instruments in detail.

The factor A is, of course, different for each color, so that if it is determined for a particular color by means of a known extinction coefficient and a known concentration, in all subsequent work that particular color must be employed.

There is no mathematical relation between the extinction coefficient and the wave-length of light, but a relation may be determined experimentally by means of a spectrophotometer.

Let us consider a simple blue solution, for example, a salt of copper. The general character of the absorption curves for different concentrations is shown in Fig. 1.

The curves illustrated in the figure show the relation between the extinction coefficient and the color. The extinction coefficient is a measure of the absorption of the solution.

There are several facts to be observed about these curves which are of fundamental importance to *spectro-colorimetry*. Since the solution is blue the blue region of the spectrum is of course least absorbed while the absorption in the red is the greatest.

A solution of zero concentration would transmit 100 per cent of the light incident upon it, neglecting the absorption of the solvent, and its extinction coefficient e would be $e = 2 - \log 100 = 0$. Its absorption curve would consequently be represented by the horizontal line A. A very dilute solution, say a concentration of 1 per cent, would transmit nearly 100 per cent in the blue but might transmit considerably less in the red, hence the shape of the 1 per cent curve.

Since e is directly proportional to c there is a constant difference between the successive concentration curves as shown in the figure. For instance, along the vertical line, B, there is the same interval between curve 1 and 2 as between 2 and 3, etc. The same is true for the vertical line C or D, but the

difference here in the red is considerably greater than in the blue region, as might be expected.

It is therefore clearly seen that in working with weak blue solutions more accurate results could be obtained if the red part of the spectrum were utilized instead of the blue. With the ordinary colorimeter, what the eye sees is the resultant effect of all these colors, and since the blue predominates the solution appears blue.

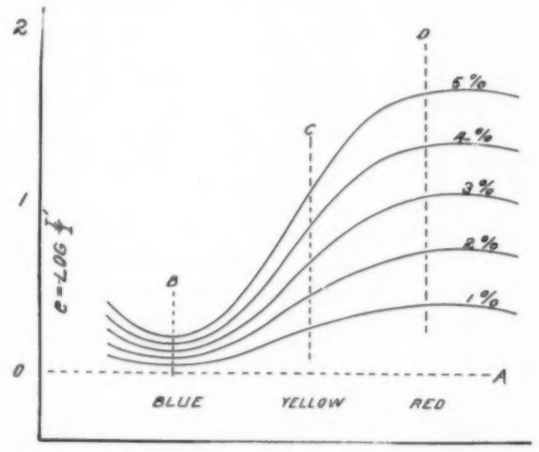


FIG. 1.—ABSORPTION CURVES FOR A BLUE SOLUTION

The advantage of the spectrocolorimeter or the spectrophotometer for accurate work is readily seen. The spectrophotometer has this decided advantage over the spectrocolorimeter, namely, that no standard solution is required. Moreover, only a small sample of the solution whose concentration is desired is necessary. The spectrophotometer may also be used for very dense and for very turbid solutions.

Cells

In making a photometric comparison of two light sources it is desirable that the two fields of view be uniform in intensity and that the boundary line between them be as small as possible. It is impossible to make an accurate setting when the two fields are separated by a line of any appreciable width.

Some instruments employ a simple rectangular glass cell; *a*, Fig. 2, and utilize the liquid surface of the solution to divide the incident beam. Due to the meniscus, however, the dividing line between the fields will not be narrow and this cell is therefore unfit for accurate work, without some modification.

A glass cube, *b*, Fig. 2, with optically plane sides is sometimes employed in which case the top surface of the cube forms the dividing line. This cell is often used where it is possible by special optical devices to separate the two beams a small amount before they reach the slit.

The third cell, *c*, Fig. 2, has a curved bottom and the cube which is used with it also has a curved bottom so that when

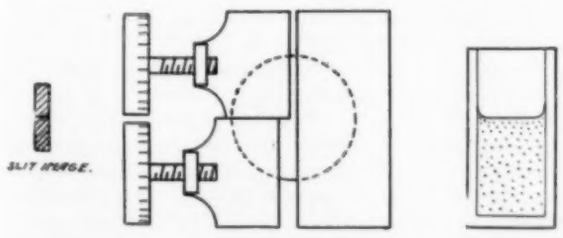


FIG. 3.—DOUBLE-SLIT APPARATUS

the latter is placed in the solution the sides of the cell and the sides of the cube will always be parallel.

The sides of these cells are either held together by cement or by means of clamps. The latter form of cell is more easily cleaned, and for some solvents this is an advantage.

In the case of volatile solutions it is well to use stoppered cells, *d*, Fig. 2.

The Krüss Universal Spectral Apparatus

This instrument is similar to the ordinary prism spectrometer except that the collimator slit is double and it is also provided with an ocular slit which excludes all of the spectrum except the desired color.

Each of the slits is actuated by means of a screw as shown in Fig. 3 and the screw heads are divided into 100 divisions. The cell is placed directly in front of and close to the slit face in such a manner that the level of the liquid is in line with the dividing line between the two slits.

Upon looking through the eye-piece, with the ocular slit removed, one sees two spectra separated by an ill-defined line. If the cell with the cube is employed this line may be made narrower and considerably sharper.

Now if the ocular slit is inserted and opened to a width of about 4 or 5 mm., two uniform fields of homogeneous light may be obtained. The ocular slit is, of course, magnified by the eye-piece, but in order to make a good setting it must not

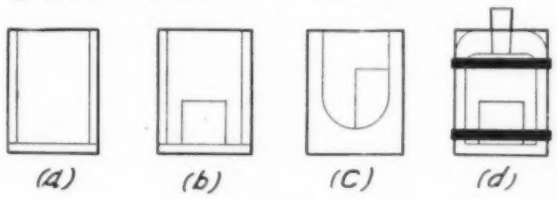


FIG. 2.—DIFFERENT TYPES OF GLASS CELLS

be too narrow. Moreover, homogeneous light is not obtained if the slit is open too wide. For example, if an observation were made upon a band narrower than the width of the slit then it is readily seen that the field formed by the band would not be uniform, but would fall off in intensity to either side.

Care must also always be taken to avoid setting the ocular slit upon the edge of a band where the intensity changes rapidly. For instance, suppose that a particular blue solution (Fig. 1) were so concentrated that the red region of the absorption spectra could not be used. The yellow region would, of course, transmit more light and consequently make the photometric setting possible, but a slight change in the wave-length would introduce a considerable change in the intensity so that if the instrument were, for subsequent work, reset for the same color, this adjustment would have to be made with extreme care.

In the red or blue region, however, the curves are nearly horizontal so that a considerable change in color is required to produce a significant error in the intensity.

With the type of slit shown in Fig. 3, a slight error will result if the difference in the widths of the upper and lower slit is too great and it is consequently advisable to use a symmetrical slit, *i.e.*, one in which both jaws of each slit open an equal amount, Fig. 4.

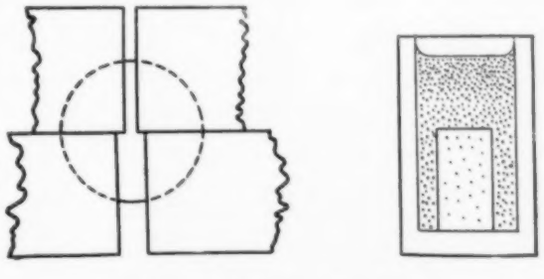


FIG. 4.—SYMMETRICAL DOUBLE SLIT

The scale which is attached to the telescope, or observing tube, of most of these instruments is either divided into circular degrees or arbitrary divisions so that the wave-length of light used cannot be read directly from the scale. This is not necessary, however, for it does not enter into any calculation and therefore an arbitrary scale is sufficient.

If, for example, the telescope reads 59.3 when the absorp-

tion ratio is determined for copper sulphate then the telescope must always be set for 59.3 when this particular absorption ratio is used for the determination of the concentration of a copper sulphate solution.

Sometimes the principal solar absorption lines A, B, C, D, etc., are also engraved upon the scale, but they only serve as a rough universal scale. When one observer makes the statement that in a particular process the absorption ratio for a given substance should be determined in the region of the D line, then the process may be readily duplicated by the user of any type of instrument.

The method of making an observation with any double slit instrument is briefly as follows:

Both slits are opened to any convenient width, say to the 30 mark, and then the source of illumination is adjusted until the two spectra, as observed through the eye-piece, are equally bright. This adjustment must then be verified by resetting one of the slits, say the upper one, several times.

If the average of the readings thus obtained is 30 or very nearly 30 then the initial adjustment is sufficiently close. If, however, it deviates too much from 30, then the lamp must be shifted slightly and another series of readings obtained by operating the slit. This operation must be carried out until the upper slit reads the same as the lower one.

Both slits are then opened to the 100 mark and the cell containing the solution is placed in front of the slit face and adjusted until the level of the solution is in line with the dividing line between the upper and lower slit.

If the light is not too bright both slits may be opened to 100 instead of 30 and moreover if, for subsequent work, all the photometric balancing is to be done with the upper slit only, then it is, of course, not necessary that the lower one read 100 or any other particular number, so that when the lamp is roughly adjusted the upper slit may be set to 100 and the final adjustment may be carried out by means of the lower slit.

This method of making the initial balance is evidently much easier than adjusting the lamp. In making this initial balance the ocular slit may be set on any convenient color since both spectra are due to the same source and are therefore identical.

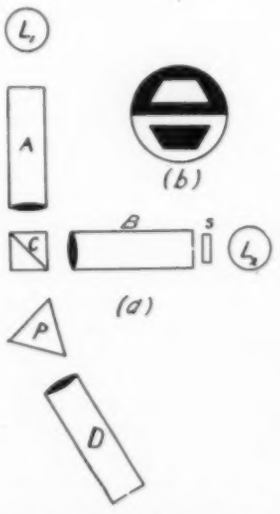


FIG. 5.—LUMMER-BRODHUN SPECTROPHOTOMETER

When the cell, containing a colored solution, is in position the lower spectrum will be weakened and in order to bring both fields to the same intensity it will be necessary to narrow the upper slit.

Suppose that an intensity balance is obtained when the upper slit is set at 30; this means that 30 per cent of the incident light is transmitted by the solution and, therefore,

$$I'/I = 30/100 \text{ or } I' = 30$$

whence from (2)

$$e = 2 - \log I' = 2 - \log 30 = 0.523.$$

If the concentration is 4 per cent then the absorption ratio is

$$A = c/e = 4/0.523 = 7.65.$$

Now imagine that an unknown concentration of the same solute and solvent requires a reading of 24.0, on the screw-head of the upper slit for a balance, the extinction coefficient then becomes

$$e = 2 - \log 24.0 = 0.620$$

and the unknown concentration is, therefore,

$$c = A\,e = 7.65 \times 0.620 = 4.74.$$

This simple method admits of easy calculation but for wide ranges of concentrations it is sometimes necessary to manipulate both slits. For extreme concentrations, the upper slit would have to be made so narrow that an accurate adjustment is impossible, since a very narrow slit means, of course, a considerable loss of light.

If we had a dense solution which would affect only a 3 per cent transmission, instead of diminishing the upper slit to 3 we could set the lower slit to 300 and diminish the upper one to 9.

If several different widths of cells are used and if the absorption ratio is determined for each then all the adjusting may be done with one slit. Since the concentration varies inversely as the length of the absorbing layer, if the absorption ratio is determined experimentally for one cell, it may be calculated for any other. For example, if the absorption ratio, A, is 8.24 for a 10 mm. cell, then for a 20 mm. cell it would be equal to 4.12.

Whenever the glass cube is used, the adjusting is, of course, always done with the lower slit.

When the two uninterrupted beams are first brought to equality, it is not necessary to have the empty cell in place while adjusting the lamp, since it causes the same absorption of each beam. However, if the glass cube is used then its absorption will introduce a slight error which may be easily avoided by adjusting the intensity of the two spectra with the empty cell and cube in position. The error, however, is not worth considering when only approximate results are required since the transmission coefficient of 1 cm. of glass is about 98 per cent.

Let us suppose that the instrument is first balanced without the cell in position and that the filled cell, with cube, requires for a balance a reading of 40 on the lower slit when the upper slit is set at 100. Neglecting the glass cube we obtain for the extinction coefficient

$$e = 2 - \log 40 = 0.398.$$

But since the cube transmits only 98 per cent of the light incident upon it and not 100 per cent, the true extinction coefficient is

$$e = \log 98 - \log 40 = 0.389.$$

In refined work the cell should always be filled with the solvent to be used and should be placed in position when the initial balance is made.

In order to eliminate the trouble of carefully adjusting the cell each time so that the top face of the cube is in line with the division line between the slits, a Schottländer double collimator or a Hüfner reflecting prism is sometimes used in connection with the Universal spectrometer, but as there are more precise instruments which do not require this delicate cell adjustment, these rather complicated appliances need not be considered.

Lummer-Brodhun Spectrophotometer

The usual form of the Lummer-Brodhun spectrophotometer is shown in *a*, Fig. 5.

A and *B* are two collimators, the slits of which are illuminated by two frosted globe incandescent lamps (16 c.p., 110 volts). The telescope *D* is provided with a slit instead of an eye-piece so that on placing the eye close to this slit one sees the face of the Lummer-Brodhun cube, *C*, which has the appearance shown in *b*, Fig. 5.

The dispersive prism, *P*, spreads the light into a spectrum so that there is a succession of colored images of the cube in the plane of the ocular slit. Since, however, the slit transmits only a narrow region of the spectrum, the eye sees the cube illuminated in only one color.

The cell *S* may be placed before either slit and since the two slits are independent of each other the illumination may be controlled by moving either lamp to or from the slit it illuminates. Thus with the cell, filled with the solvent, in front of one of the slits both may be set to the 100 mark and the initial balance made by adjusting the lamps or by simply manipulating the slit which receives the absorbed light from the cell. The other slit must, of course, be kept at the 100 mark.

The disadvantage of this type of photometer over that in

which both slits are illuminated by the same source is that the two lamps must be kept constant, but in the latest form of this instrument the lamps are rigidly clamped to the frame of the instrument so that the only change in intensity that may occur is that caused by fluctuations of the voltage. Although both lamps are on the same circuit and subjected to the same change in voltage, it does not follow, of course, that the corresponding change in intensity is the same in each lamp. This would be the case if both lamps were practically similar and it is not difficult to select two lamps which will fulfill all industrial requirements.

If the lamps appear equally bright to the unaided eye and if they balance for all parts of the spectrum there will be no appreciable difference in their intensity due to an increase or decrease of the voltage. The initial balancing of the two fields will then hold good for a number of hours of constant use.

With this type of Lummer-Brodhun spectrophotometer it is only necessary to have the solution cover one of the slits and the time saved in adjusting the cell more than compensates for the time required to rebalance the two fields, in order to make sure that a change of voltage has not disturbed the original balance.

In order to make a photometric balance with the type of Lummer-Brodhun cube shown in *b*, Fig. 5, the light from one source is varied by adjusting one slit until the semi-circular portions have the same brightness, and when this condition obtains the two quadrangles will be equally bright, but there is always a slight difference in their brightness and the bright-

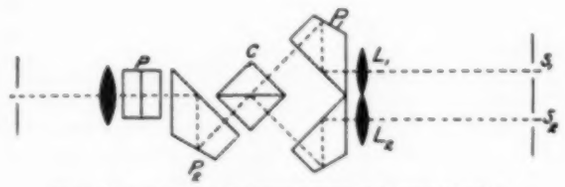


FIG. 6.—LUMMER-BRODHUN DOUBLE COLLIMATOR

ness of the semi-circular backgrounds. Such an arrangement is known as a *contrast photometer* and it is much more sensitive than the ordinary type.

The observing tube is provided with a scale which is read by means of a small telescope and miniature 6-volt glow-lamp. The lamp is usually run on three storage battery cells and as the scale cannot be seen without the aid of this lamp the arrangement is not practical since all commercial laboratories are not provided with storage batteries. The screws actuating the slits are not within easy reach when the eye is at the observing tube and moreover the divisions on the screw heads cannot be read from the position occupied by the observer when looking through the observing tube.

These disadvantages are overcome in some other instruments which lack the accuracy of the Lummer-Brodhun. To be sure these points have nothing to do with the working principle of the instrument; however, they are very essential to the operator whose time is valuable and the failure to appreciate their importance has in many instances retarded the progress of such methods in industrial laboratories.

For industrial purposes it is far better to employ an instrument by means of which one may obtain quickly a large number of fairly accurate observations than to employ a very sensitive instrument which requires more time to make a very few extremely accurate observations. In using any instrument which requires the eye to match colors or balance intensities the best method of making certain that your results are correct is to repeat the observations.

By means of a double collimator and reflecting prisms, the Lummer-Brodhun cube may be adapted to the double slit photometer. The optical system of the Lummer-Brodhun double slit instrument is shown in Fig. 6.

Light from a suitable source of illumination passes through the double slit S_1 and S_2, is rendered parallel by means of the two lenses L_1 and L_2 and thence passes to the Lummer-Brodhun cube C, by means of the reflecting prism P_1. By means of a second reflecting prism P_2 the light is transmitted through the dispersive prism P which draws out the image of the Lummer-Brodhun cube into a spectrum.

If the lamp is fastened rigidly to the frame of the instrument then a change in its intensity, due to a change in voltage,

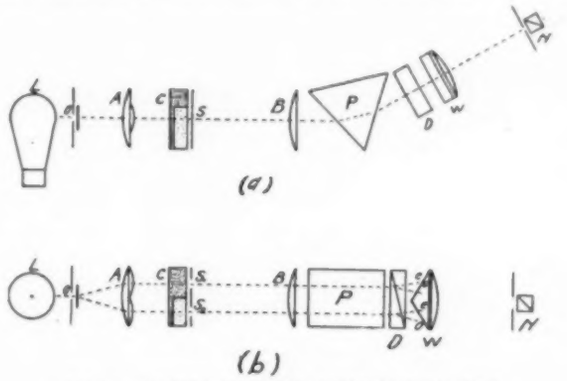


FIG. 7.—KOENIG-MARTENS SPECTROPHOTOMETER

will not cause any error in the determination of *e* since the light through both slits is changed in the same ratio.

König-Martens Polarization Spectrophotometer

The optical system of this instrument is shown in Fig. 7; *a* is a horizontal section through the instrument and *b* a vertical section.

Light from a suitable lamp *L* passes through a small aperture *O* which is covered with ground glass. By means of a double lens *A* two parallel beams are produced which illuminate the two slits S_1 *and* S_2. A cell of the type shown in *c*, Fig. 2, is placed in front of the two slits.

The slits are thus always equally illuminated regardless of the position of the lamp, since the two beams originate from the same source of light. If the lamp were moved slightly to one side, the ground glass would still be uniformly illuminated. In reality the two slits are one which is divided by means of a tongue, hence they are always open the same amount.

From the slits the light is again rendered parallel by a lens *B* and by means of a dispersive prism, *P*, the slit images are spread out into two spectra, *a*, Fig. 8, which are separated several millimeters.

These two spectra are next divided into four, *b*, Fig. 8, by means of a double image prism *D*. The ordinary and extraordinary images thus produced are plane polarized with their vibrating planes mutually perpendicular. The short horizontal and vertical lines in *b*, *c* and *d* indicate the direction of vibration.

By means of a wide angle wedge *W*, which is part of the telescope objective, the two inner images are thrown together, *c*, Fig. 8, while the outer images are excluded from the telescope.

When the eye is placed at the ocular slit, which is in the

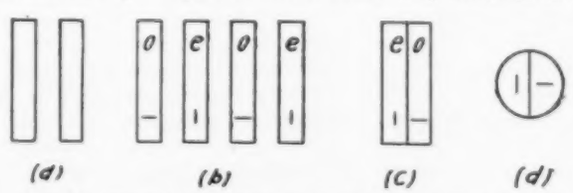


FIG. 8.—SPECTRA PRODUCED BY THE KOENIG INSTRUMENT

focal plane of the telescope objective, it sees the wide angle wedge, *W*, illuminated by light of one color. As the telescope or observing tube is rotated about an axis through the prism *P*, thus causing the ocular slit to pass from one end of the spectra to the other, the field is alternately illuminated by the prismatic colors, red, yellow, green, etc. The field of view has the appearance shown in *d*, Fig. 8.

If a Nicol prism, N, Fig. 7 (*i.e.*, a prism which transmits only plane polarized light), is placed between the eye and the ocular slit with its transmission plane vertical, the left field will appear bright, but the right one dark, since it is illuminated by light whose vibrations are perpendicular to the transmission plane of the Nicol.

When the Nicol is placed with its transmission plane horizontal it will transmit light from the right field but exclude all light from the left one so that the left field appears dark.

Now if the Nicol is turned 45 deg., both fields will appear equally bright and for any other position of the Nicol the ratio of the intensity of the light from S_1 to the intensity of the light from S_2 is expressed by the simple relation

$$I_1/I_2 = \tan^2 \phi$$

If the cube covers slit S, then the cotangent is used instead of the tangent.

From the theory of extinction coefficients

$$e = -\log (I'/I).$$

But I_1/I_2 is the ratio of the transmitted light to the incident light if the instrument is balanced when the Nicol scale reads 45 deg. and the empty cell is in the position indicated, hence the extinction coefficient is

$$-\log (I_1/I_2) = -\log \tan^2 \phi = 2 \log \cot \phi.$$

The absorption ratio A is a constant so that the factor 2 may be dropped. For this particular instrument we may define the extinction coefficient by the equation

$$e = \log \cot \phi.$$

The concentration then becomes

$$c = A\, e = A \log \cot \phi.$$

The log cotangent of the angle, through which the Nicol must be turned in order to produce a photometric balance, may be obtained directly from a logarithmic table so that when the reading of the Nicol scale is obtained the extinction coefficient is readily determined.

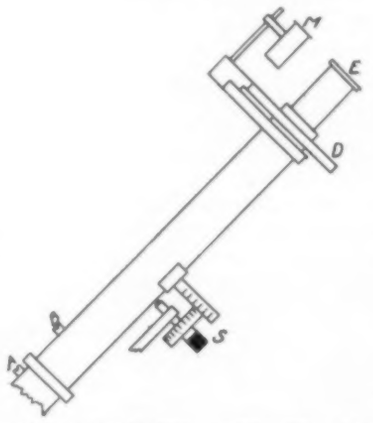


FIG. 9.—OBSERVING TUBE OF THE KOENIG-MARTENS INSTRUMENT

The method of determining the concentration of a particular solution by means of observed data may be made clear by a simple calculation. Suppose a 10 per cent solution gives a reading of 26.4 (*i.e.*, 26 deg. 24 min.) on the Nicol scale. The extinction coefficient is, from the above equation

$$e = \log \cot \phi = \log \cot 26.4 = 0.304$$

and the absorption ratio is therefore

$$A = c/e = 10/0.304 = 32.9.$$

If an unknown solution gives a reading of 18.6 deg. its concentration is found to be

$$c = A\, e = 32.9 \log \cot 18.6 = 15.5 \text{ per cent.}$$

The Nicol prism is attached to a circular disc, D, Fig. 8, which is divided into angular degrees and this scale is observed by means of a small magnifier M which is close to the eye-piece E.

The telescope, or observing tube, is rotated by means of a screw S, the head of which moves over a scale divided into arbitrary divisions. This scale is used for indicating a particular position in the spectrum.

This instrument has several distinct advantages over the others described. The two slits have always the same width and this prevents any asymmetry of spectra. The device for varying the intensity is within easy reach and the attached scale may be quickly and accurately read by moving the eye a short distance. The screw that rotates the observing tube is also within easy reach and the observing tube scale may be easily read from the position occupied by the observer when making a photometric balance. All of the optical parts are completely enclosed and this makes the instrument more robust. Moreover, all extraneous light is excluded.

Due to the rather complicated optical system, however, this instrument only transmits about one-third as much light as the double-slit spectrophotometer and this fact renders it unsuitable for very concentrated solutions. This difficulty may be overcome to some extent by using cells of short length. In the most improved form of this spectrophotometer, rather long cells may be used so that observations may be made on very dilute solutions. It is thus seen that the instrument has considerable range.

Both the double image prism and the wide-angle wedge may be rotated slightly by means of set-screws, A and B, Fig. 9, so that when the Nicol is set at 45 deg. the two fields may be brought to equality. It is never necessary to repeat this adjustment after the instrument is once set up, unless it receives some rought handling which might disturb the optical system.

The method of completely calibrating a spectrophotometer and some industrial applications of the spectrophotometer will be fully considered in a concluding article.

University of Illinois,
Urbana, Illinois.

Mill Physiology

By Stephen L. Goodale

Many technical articles on mills and ore dressing deal with plan and structure, machine details, etc., or what may be called mill anatomy; and the literature contains formidable masses of tabulated data on mill details from all over the world. All this is of the greatest value in the study of the subject, but is it not probable that too much emphasis has been laid upon the descriptions of machines in themselves, flow sheets, sizes of launders, grading analyses, screen sizes, stamp weights, etc.? Other types of discussions must doubtless be built upon the simple mill descriptions.

One kind of study, that of the mill in operation in its parts and as a unit, its "life processes," which I may call "mill physiology and hygiene," is occasionally emphasized in print as it is forced upon the millman's attention in practice; and is, I believe, of the greatest value to those students who can make real use of it—in some such way as a few good ladies are able to make successful pie from the cook book instructions without experience, and if they have a good cook book.

I am interested in this idea just now from the point of view of trying to offer students the most practical instruction along these lines. I am strongly of the opinion that much more can be learned of these practical affairs from "book larnin' " than is usually the case. The possibility of this depends, of course, largely on the student himself, and his ability to use books, but also in a very important way upon the literature available to the man.

In papers on gold milling there is often found a description of the make-up of the plant and not much more, and it is left to the reader to infer that because the selection and arrangement of machinery are of a certain kind, they are as they ought to be. Certainly this inference is not always justified, although perhaps not greatly in error if one is studying a successful mill.

Let us go a step beyond this, and inquire what the mill does in action. How do the various pieces of apparatus behave, each of itself, and how do they fit together in operation? What has been the reaction of the operation of the mill upon the mill itself, and how has it grown to what it is from what it was to begin with? For an instance, because of what overflows of launders or stopped-up launders or both have they been reconstructed to their present size, outline and grade?

In this paper I can but outline a few illustrations of this, leaving to the imagination of my readers the task of filling in such details as they wish. It is some time since I have been able to watch closely for a length of time the operation and development, the daily behavior and misbehavior, and

those little changes and improvements which are constantly being made in most successful plants, or, as we may say, the "physiology" of any gold mill.

Several months ago I spent a pleasant afternoon with a non-technical man who is trying to run a mill, and he entertained me with a story of his mill experiences and difficulties—and, by the way, such discussions as I have in mind would be largely connected with mill difficulties. My remarks on this plant are based almost entirely on his statements to me at the time as I recall them; and some of my inferences may not be justified.

This gentleman had but recently taken charge of the mill himself. Although a wide-awake and very intelligent and energetic man, he was without gold milling training or experience, and said he had no time to read either the text books or technical journals because the mill itself kept him so busy. He showed excellent ability in being able to secure ore to treat in a district where the competition among the mills for ore is very keen. That is, he was able to inspire confidence in the shippers of ore; which is especially essential where the mill is treating ore for the shipper, not buying it outright, but giving each producer just what amalgam and concentrates are obtained from his ore.

The plant had been operated at a loss. The new man attributed this loss mostly to theft of amalgam, and had consequently fired his superintending millman and taken charge himself. The business had been conducted on the basis of purchasing ore on sample to treat by amalgamation and concentration. On taking charge of the plant the new man ceased purchasing ore on sample, and started, according to the more usual custom of the district, to treat the ore for the account of the producer, this probably being a wise business move. A high tailings loss would not be so quickly felt in the mill balance sheet!

The day of my visit this operator was tearing out an excellent tube mill which had cost some $3,000 in order to replace it with some type of grinding pan. Incidentally he had thrown out the classifiers which were in, and flooded the mill with others. He appeared to like to have things changing.

The mill had the usual crusher and grizzly equipment and some fifteen stamps. Very fine mesh screens and high discharge were used on the batteries. The coarse sand from the stamps was sent to the tube mill, which was, therefore, run on an extremely light feed, as there were only fifteen stamps to provide it. The tube mill was being rejected because the few stamps equipped for such fine crushing already could not keep it busy, and because of the large amount of power it consumed, this power being very expensive.

I believe that at this particular plant the equipment of tube mill in connection with stamps had not been thoroughly put through its paces before the change was decided upon to a grinding pan. The tube mill was probably being thrown out without a full trial of its possibilities of adaptation. It may be true that for this ore and treatment the two machines are not the best to work in series together, and that a grinding pan would be preferable to follow the stamps; but better commercial results can sometimes be secured by adapting a machine already installed than by throwing it on the dump heap to put in a new one at increased expense. This is true in spite of the great variety of machines made, each one better than any other in some small particular at least, and the fact that for a machine to be good, it must be good for the particular use in view.*

The old saw comes to my mind that "There are more ways than one to kill a cat besides choking it with cream." Some ways may be cheaper, and yet leave just as dead a cat. And in this mill it is probable that the tube mill could have been made to do well commercially by some adaptation of other equipment at slight cost to save and utilize the large capital outlay in the tube mill. It seemed to me that this mill needed a business doctor instead of changes in its major equipment, a practical, technically educated mill man to put it through a period of experimentation with the machinery already installed, making any small changes necessary, to see if a little ingenuity could adapt it commercially to the work to be done.

Now for the point of my remarks on this plant: A flow sheet of this mill with description of machinery taken before this change might get into a text book and start another man to copy it without due consideration of its work or what kind of ore it was best suited for—if any. By the time the description had gotten in print, the pattern would have materially changed. Or possibly the same might have occurred after the change, in which case a few remarks on the change would doubtless be inserted. It seems to me that the story of the change, including the reasons leading up to it, why that particular change was adopted rather than another, and at least some results of the new arrangement, would make far more instructive and entertaining reading than a description of the mill either "before or after taking." True, the full history of this change is not yet made; no one knows yet but that the grinding pan may follow the tube mill to the waste heap.

A larger number of "physiological" chapters in our textbooks might contribute to lessen the apprenticeship necessary after school. Such chapters would give, for instance, a careful account of such a change as that mentioned including a recital of the symptoms of poor digestion, a statement of those methods of cure which prove defective, and many general details, etc. Students of this kind of thing can, if they will, profit by other men's experience and almost make it their own, so that a shorter term of apprenticeship than is now usually the case might fit them to take charge of affairs. I believe that we cannot do away with the necessity of experience for our young men. In fact, my observation of late has been to emphasize the need for our students—especially those in some Eastern schools—to undergo a real period of apprenticeship to round out their technical training.

I have in mind two other instances, in both cases successful mills, with which I was quite familiar at one time: I wish to cite these now, with close reference to each other, and this question.

One mill crushed wet with stamps, then amalgamated, classified roughly, reground the coarse sand in Huntingtons, re-amalgamated, concentrated, and cyanided the sand tailings, rejecting the slimes overflows which carried $2 to $2.50 usually—rarely up to $4— per ton, and which amounted to some 35 tons or more per day. The work of this mill was excellent, the company was paying large dividends as the ore was high-grade, often $30 or better per ton at that time. They were, however, sending down the creek in the slime overflows a large amount of money, of which, I am sure, a considerable portion could have been recovered with a fair profit. Of course, at the present time, scarcely any mill manager would think of wasting such material, easily amenable to cyanidation as it was and even at the time when I was familiar with the details slime handling machinery had been developed to a point where this material certainly could have been treated successfully. I mention this rather ordinary case to emphasize the next one which seems to me very striking.

This second mill crushed dry with rolls following a gyratory breaker, it being necessary to dry the ore as the mine was unusually wet. The drying acted also physically to render the ore somewhat porous. The finely ground dry ore was charged into vats, saturated from below with cyanide solution, and then leached for seven days, more or less, according to the ore supply and other circumstances. Strong sodium cyanide solutions—7 lb. KCN equivalent to the ton—were used because of the preponderance of silver. For a considerable period this ended the treatment. The tailings indicated more than usually satisfactory extraction, assaying only from one to two hundredths in gold.

But the idea was conceived of amalgamating after cyaniding, and after some trials this treatment was applied to all

*This is well illustrated in another mill I visited recently where Akins classifiers are used at one point where it is desired to secure a sand reject with especially low moisture content and Dorr classifiers are used where it is especially desired to get the sands free from slimes. These two machines are very similar, but have just about that difference in operation.

the tailings, the sands being sluiced from the leaching vats over amalgamating plates after leaching and washing. The expense of this treatment was slight, and every month a little gold brick was obtained from the plates sufficient to pay for the cost many times over, in spite of the low assay value of the material. The gold condition there was that most of it was very fine and easily dissolved, but that a little was coarse and rusty, being cleaned but only slightly dissolved by the seven days' treatment, and it was from this coarse gold that the added saving by amalgamation was made. This particular experience, by the way, has always seemed to me to indicate strongly the value of the microscope in ore dressing investigation.

The ore at this mine was of much lower grade than that at the former, seldom over $8 to $8.50 per ton in both gold and silver, and of course, closer economy had to be practiced here. The point of special interest to me is the development of a saving of some $800 to $1,000 per month at one plant from tailings assaying usually only 20 cents to 40 cents per ton, and the suggestiveness of this when thought of in connection with $2 material in a fine state of division going to waste. Why not apply the experience at one plant to the condition at the other?

In the history of the treatment of Cripple Creek ores from the early unsuccessful attempts at amalgamation, through the earlier work of cyaniding, from that to chlorination, along with the development of the machinery for carrying on the process, the trials of chlorination in barrels and in open vats, the different methods of generating chlorine, etc., etc., the losing fight of chlorination against the better machinery of cyanidation, and the present development of cyaniding—in all this history of changes is ample opportunity for a number of papers which would illustrate not so much what the mills were at any particular time, but rather the daily operation and growth of milling processes, and would be of great value in teaching young men how to attack new problems. Some excellent papers of this kind, of course, already exist.

I may in closing mention very briefly some interesting recent developments of milling in the Cripple Creek district. For a long time certain mills there have been doing well commercially with what some persons might consider a very crude treatment. In those mills the ore is left very coarse, possibly being put through a 3- or 4-mesh screen, or even in some cases simply run through crusher and rolls and placed in vats for leaching without screening. This treatment is usually considered to be applicable only to the oxidized ores of the district, of which there seem to be very large supplies at certain of the mines. The success of the coarse crushing depends upon the location of the gold being in the seams of the rock, along which in crushing the rock breaks, thus exposing the gold minerals to the leaching solution without fine grinding.

The three latest operating mills present a very interesting development of this treatment—which is so much developed as to present almost a striking contrast. In all these mills fine grinding in tube mills is practiced on at least a part of the material. The details vary much in the three plants. In two cases of late practice the rock is broken down to about walnut size and then screened and only the fines saved, the coarse stuff being sometimes washed to recover any dust adhering. This treatment for the cost of crushing and screening secures from an ore running only about $2 or lower a product which may carry $7 to $9 value per ton, which is then further treated by cyaniding. The further treatment at one plant includes grinding the above product in roller mills in a weak cyanide solution, and then concentrating on modified Wilfley tables. The tailings from these tables are dewatered, slightly washed and then discarded, as they are worth scarcely more than it would cost to treat them more closely. The concentrates are cleaned on a second set of tables and shipped to the smelter; and the middlings from this set of tables is reground to slimes and cyanided by agitation. The pregnant solutions are precipitated by zinc dust. The slime overflow from the sands of the first Wilfleys is also cyanided by agitation. This treatment is seen to be really a logical development of the former in that it is still the fine breaking material which receives most attention; there having been added from another source the item of concentration on shaking tables.

The student can get from textbooks descriptions of many plants and thus familiarize himself with different types of mill adapted to different ore. No one can learn milling from textbook study or class-room lecture alone; but could we not further assist the student by relating to him more of "mill physiology," tell him of the "life processes' as it were of the mill in action, and thus prepare him better to take up the direction of such work? I think so.

University of Pittsburgh, Pittsburgh, Pa.

Determination of Oxygen in Copper and Brass

A paper by Mr. **T. West** on this subject was presented before the recent meeting of the (British) Institute of Metals.

The author has worked out a method for the estimation of oxygen in copper and brass, using carbon monoxide as the reducing agent. In the first instance the conditions for estimating oxygen in copper were determined by comparative tests with the customary method of reducing with hydrogen. A temperature of about 900° C. was found to be sufficient, the time varying between two and three hours.

Since any oxygen in brass probably exists in the form of zinc oxide a number of experiments were next carried out under varied conditions to ascertain how far the reduction of zinc oxide by carbon monoxide, and weighing the resulting carbon dioxide, could be relied upon as a test for zinc oxide. It was found that provided the temperature reached 1050° and the gas current was sufficiently rapid the amount of carbon dioxide formed corresponded closely to the actual weight of zinc oxide taken. Interesting variations in the method of condensation of the zinc were obtained. Experiments were then carried out on mixtures of copper (containing known amounts of oxygen) and zinc and these gave satisfactory results. Finally tests were made on samples of pure brass and these showed that ordinary brasses of good quality contain on an average about 0.002 to 0.003 per cent. of oxygen. Tests were also carried out on condenser tube brass containing about 2 per cent. of tin, and also on German silver. In these cases a rather surprising result was obtained, since a deposit of carbon was found adhering to the metallic surface after cooling down in an atmosphere of carbon monoxide. The method, therefore, can only be applied to the estimation of oxygen in brasses containing copper and zinc (with the ordinary amounts of commercial impurities) and not to spiral brasses containing tin or nickel, on account of their decomposing action on carbon monoxide.

Annealing of Gold

A paper on this subject was presented by Dr. **T. K. Rose** before the recent meeting of the Institute of Metals.

In the first part of the paper, the effect is shown of the presence of small quantities of impurities on the temperature at which gold can be annealed. This is the first investigation of the kind, and although the exact quantitative effects in the case of metals other than gold are doubtless different from those recorded in the paper, indications are afforded of the general results which may be expected. The effects are remarkably great. For example, the addition of only 0.002 per cent. of hydrogen raises the temperature of annealing of gold from 150° to over 300°, and 0.05 per cent. of copper raises it to 250°. Further additions do not raise the temperature proportionately.

It is further shown that the annealing of rolled gold begins by the complete softening and recrystallization of some of the laminated crystals of which the metal consists, the other laminæ remaining unaltered until more time has elapsed or the temperature has been raised. Accordingly partially annealed metal consists of alternate strips of hard and soft material, having weak places where its rigidity and resistance to rupture are little higher than those of fully annealed material.

The paper is illustrated by curves and photomicrographs.

Induction-Furnace Notes

By Joh. Härdén

In the following a few notes of details and readings on an induction-furnace plant, installed some short time ago, will be given, as an example of what can be done in this class of furnaces when used for high-class crucible steel making. The author ventures to surmise that the notes will be of some interest to the practical steel maker, since the facts given are taken from actual practice with a furnace plant which has now been in operation for some time and all uncertainties of the commencement are overcome.

Early in 1909, a large crucible steel making firm decided definitely to install a Kjellin induction furnace as a supplementary to their pot smelting. This decision was as much more recommendable as the raw materials consisted chiefly of Swedish bar ends, pig iron and high-grade steel scrap; consequently a most effective "melting machine" only was desired, refining from phosphorus and sulphur being unnecessary. Great importance, however, was laid on the question of elimination of gases and slag incrustations, as well as a high thermal efficiency, so as to keep the melting costs low.

The furnace was consequently designed accordingly; the writer was entrusted with the pre-calculation and general design, while a large engineering firm was called in for the construction of the tilting gear, staging and other auxiliary mechanical details.

The furnace was originally ordered for a tapping capacity of 1 ton; being fully acquainted, however, with the prevailing conditions, the writer thought it most advisable to provide for a considerable margin. This precaution proved fully justified, because the charge has subsequently been gradually increased up to over 2 tons.

Seeing that no particular refining was required, the bath section was kept rather deep and narrow, giving a smaller slag surface. In this way the thermal conditions could be kept better under control, and a small remainder only of the charge would be required for recharging.

The pre-calculation showed that the most economical dimensions for the hearth would be:

Middle diameter	66 in.
Height	11 in.
Width	63 in.

These dimensions were adhered to in the construction, with the exception that provision was made for deepening the bath so as to allow fully 2 tons of steel.

The above dimensions would give a capacity of 3960 lb., permitting of a tapping of 2700 lb.

The electrical data as calculated for this quantity proved to be very accurate when tested under running conditions; they were as follows:

Resistance of the bath $= 18 \times 10^{-4}$ ohms.
Inductance $= 2324 \times 10^{-9}$ Henrys.
Secondary current = 37,900 amp.
Power factor at 15½ periodes 0.633.
Magnetic saturation, 8550 lines of force per cubic millimeter square.

As will be seen from the readings given below, the lowest power factor is somewhat under the calculated figure; this is due, in the first place, to the fact that the bath, as already said, was increased in bulk, while the other factors remained unaltered. Secondly, for certain mechanical reasons, the magnet core had to be suspended and stiffened by means of heavy tie rods and brackets which formed a magnetic bye-pass which to some degree influenced the leak field. When the magnetic core and coil were tested on the bed, before the above-mentioned alterations were made, the readings gave an even higher power factor, namely, corresponding to 0.66 at full load.

The current supply was rather unfavorable, inasmuch as the current from an old 500-550 volts direct current machine was converted, by means of two slip rings, into single phase. This generator, which was of a larger size than actually required for the furnace, was *also* performing other duties at the same time, which, of course, caused certain disadvantages as to regulation.

The normal single-phase voltage was 356, which could be raised at intervals to 400 by means of altering the excitation. The total maximum power available for the furnace was given as 800 kilovolt amperes.

Originally an air-cooling arrangement was provided; the air was supplied by two fans, large enough to allow one to be disconnected for cleaning for a couple of hours. The air pressure was 5 in. water gauge, delivered through 6-in. piping and cloth filter.

Later it was found that it was very difficult to obtain sufficient pure air, free from metal dust, in spite of the filters. It was, therefore, decided to substitute water cooling, as is the usual practice in most Kjellin furnaces, leaving the air cooling as a standby. This proved very satisfactory, there being no danger whatever, if a properly designed cooling jacket is provided, since any liquid metal coming into contact with it will instantly freeze and form a secure wall. Besides, a cooling mantle of this type is a very good indicator to the furnace man as to the conditions of his lining; long before the lining is worn out thin feelers of liquid metal will slowly penetrate the thinnest part of the lining, and gradually increase the temperature of the cooling water; by careful watching of the temperature by means of a long thermometer it is quite possible to foretell exactly the state of the lining and to disrupt the operations in good time, before matters have gone too far.

The quantity of air required for the cooling of a furnace of this size is about 250 cubic meters air per square meter of the cooler-surface and this surface ought to be about 1.14 decimeter square for each kilowatt of the furnace capacity. For water cooling, 3 to 5 gallons per minute, depending on the temperature, is quite sufficient.

The furnace was suspended on two trunnions, with a tapping spout near the edge. The tilting is effected by means of a large screw spindle operated by means of an electric motor and drum controller. This proved very satisfactory, especially as the arrangement was so made as to permit back tilting as well, which was especially advantageous when starting up, and for patching up of the lining. The charging platform was arranged practically in level with the upper edge of the furnace, for the sake of easy charging of cold scrap. The portion of the platform extending over the spout was arranged to swing on hinges when tilting. Cut-out switches were provided so as to prevent over-tilting in either direction.

The instruments and switchboard are arranged direct on the charging platform; they consist of voltmeter and ammeter, kilowattmeter, recording kilowatthour meter, main switch and field regulator, together with the fittings for light and auxiliary power (tilting, fans, etc.), the whole mounted on a compact casing-pillar of steel and expanded metal.

At the commencement, the lining as used by Dr. Kjellin in his first furnaces was put in.

This consisted of:

1100	kg.	of coarse, calcined magnesite (Styrian).
22	"	fine caustic magnesite.
90	"	white Holland clay soaked in
55	"	warm water.
11	"	boracic acid.
33	"	boiling water.

The parts to be added in succession as given, and kneaded well together.

This is tamped in with hot rammers in one operation, care being taken not to interrupt the ramming more than absolutely necessary before it is finished.

This lining gives a rather good result, but is somewhat expensive, and if not handled with great skill and care, is most likely to develop vertical as well as horizontal cracks, which of course is rather dangerous. The first two linings of this kind in a new furnace are often at fault, as the men are not used to handling it.

Subsequently an ordinary tar-magnesite lining was employed; the mass consists of two parts of coarse, burnt magnesite, about ½ in. to ⅝ in. grain, one and one-half part medium, or ⅛ in. to ¼ in. grain and ¾ part fine, or 12 to 16 mesh grain. Each kind is rabbled separately with 8 to 9 per cent of hot, water-free coke-tar on a heated plate, care being taken that each grain is enveloped in a film of tar. The parts as mentioned are then mixed on the hot tray, in small quantities as it is used up, and rammed in hot. Too much material must not be mixed at one time, since the tar oxidizes and a good binding is not secured.

As soon as the ramming-in of the bottom is completed, which is the easiest part, a second squad of men is employed, in order to insure a continuous working. The work is usually conducted in this way: One man is constantly preparing the mass and carrying it to the furnace, the foreman throws it by means of a scoop in even layers in front of the rammers, four to five men walk in the casing around the mold, using heated hammer heads on pneumatic hammers. Care is taken that both sides of the mold are equally tamped.

The ramming having proceeded up to the top of the mold, a thinner layer of fluxing material, consisting of fire clay, magnesite, and iron scale is used as a finish. The ramming of a 2 to 5 tons furnace should be completed in 8 hours.

The ring-shaped mold of cast iron or wood is made in three sections, screwed together; one of the sections is smaller than the other two and wedge-shaped at the ends, so as to permit an easy removal. Lifting eyes are screwed in holes in the top and the mold removed, section after section, commencing with the smallest.

After removal of the mold, it is well to face the annular hearth with a facing of ganister, Thomas slag, scale and water, by means of a stiff brush. Several rings of cast iron or welded wrought iron, about 2½ in. high by ¾ in. thick, are placed in the furnace, the upper limb of the magnet is bolted down and current turned on. At first, only about 15 to 20 per cent of full current is used; as the fuming of the mass diminishes, more power is given until the rings *gradually* become red hot and show signs of melting.

If only one ring, having the full depth of the bath, is employed, it is likely to melt off on one spot, thus interrupting the circuit; this is avoided by using several lower rings which never break on one place. The bottom ring always melts first. As soon as this is observed, chips and borings of cast iron are filled in on the hottest part, thereby cooling this and procuring a bath proper. Soon the whole bottom is covered with molten iron, and punchings, scrap, etc., is added until the bath is full; a blanket of lime with some Thomas slag is formed and full power is turned on. The superheating is continued for about 1½ hours, so as to harden the lining. Meantime ring-shaped grooves are formed in open sand boxes and the first charge is used for casting fresh rings for the subsequent restarting. In this way, practically no material is wasted and besides, it is always wise to have a few starting rings in stock, in case one should happen to drain off too much of the charge at any time.

This first charge should always fill up the whole furnace to its full capacity; a curious fact as to the power factor may be observed during its formation. Suppose a periodicity of 16 cycles is used in a 2 tons furnace; at first, with cold rings the cosine is about 0.70 which gradually rises to say 0.75, then decreases to 0.55 just before the rings begin to melt, when it again rises to about 0.70. As the filling of the bath proceeds it sinks to about 0.63 or even, at full bath, to 0.58-0.60.

This is explained in the following way: The cold rings have a fairly high ohmic resistance, which is gradually increased as the rings are heated; this tends to give a higher power factor. As, however, the permeability also increases rapidly with the temperature from a certain point, up to about 740 deg. to 780 deg. C., or the first recalescent point, the magnetic leak field is increased more rapidly and this again causes a lower power factor. This, however, ceases at the above-mentioned point, which is shown on a sudden jump in the power factor curve, though it does not rise as high as from the start, as in the meantime more charge has been added and the metal is also well fritted together, thus somewhat lowering the total resistance. As the hearth is fully charged to its utmost capacity, the leak field is, of course, again increased, due to the counter inductive force of the secondary circuit.

It may be mentioned, by the way, that the average power factor for a given charge is a good indicator of the state of the lining. This fact is always appreciated by the experienced melter. It may be explained in the following way: Supposing the power factor is noted to be, say, 0.68 with a charge of 2 tons of about 0.5 to 0.7 per cent carbon steel during the first two or three melts; after say 150 or 200 charges it will be noted that this figure is slowly but steadily going down (sometimes earlier, at times later) and no attempt seems successful in restoring the original conditions. When it has reached say about 0.59 or 0.60, other conditions being equal, it is wise to stop and break up the lining as deep as the hearth proper, otherwise one may be fairly sure of a breaking through of the liquid steel somewhere.

Upon dismantling the lining, it will be found that a great number of fine threads of steel have slowly but surely penetrated the inner wall of the lining, until they stop and freeze against the cooling jacket. However hard the lining may be rammed in, small pores are always formed through the evaporation of the tar or binder, and the highly liquid metal is sure to find its way in. As this goes on, a sort of nest of solidified metal is formed through the inner wall around the cooler, and as this forms an excellent return for the lines of force of the leak field, this is increased and thereby the power factor lowered.

It is also necessary to take the temperature of the cooling water in the jacket once or twice during each charge, especially if the lining is "old." It should not be higher than 40 deg. to 50 deg. C. If it is found to rise higher of a sudden, it is a true sign that a larger crack has developed and a stem of steel has penetrated into the cooler.

If these precautions are always taken (which a skilled melter will do as a matter of instinct) no fear of breaking through need arise. In fact, it is to be regarded as either gross carelessness or inevitable accident, which need but very seldom occur, if a breaking through in a modern furnace is happening. The power factor meter and the thermometer, applied immediately in the outlet of the cooler, should prevent all such unwanted occurrences.

The thermometer should preferably consist of a thermocouple, connected to a millivoltmeter next to the power factor meter on the board. A mercury-thermometer inset direct in the cooler should be used as a check.

At times the millivoltmeter, calibrated in degrees C, is built as a contact instrument, ringing a bell when the temperature is too high, thus warning the melter of the danger. This was carried out at Roechlings works in Germany, but it seems to complicate the arrangement unnecessarily. Besides, the minute force acting upon the instrument does not always give an absolutely reliable contact, and it only serves to throw the melter off his guard. For this reason the arrangement is not recommended by the author.

A good lining, well built in, according to previous descriptions and carefully handled, should stand about 450 charges (463 has been reached in one furnace) when charged with liquid material; with cold charging, the life is naturally somewhat lower, on account of the mechanical strain caused by the throwing in of the larger pieces, but at least 150 to 200 should be made. The total cost of the lining, per ton of steel treated, is so small, that it does not count much when it is compared with the cost of pots and furnaces in ordinary pot-melting, especially with coke.

In former practice, one of the principal causes of ruining the lining, especially with stationary furnaces, was the treatment, or rather ill-treatment, of the taphole. Modern furnaces

are mostly made to tilt, but even here it is beneficial to the steel to make use of a "covered" taphole; considering that one has taken particular care to purify the steel from all obnoxious ingredients, among which the occluded gases are by no means the least, it is obvious that a long, open spout for tapping, in which the steel is exposed to the air, running as it is in a thin stream, thereby inevitably dragging smaller or larger lumps of semi-solid slag and crusts down into the ladle or runner, is evidently wrong.

Therefore, it is better to provide a bridge or barrier, so that the taphole is just below the normal steel level, whereby the furnace is greatly tilted after, so that the slag may run out last. In a stationary furnace, of course, the taphole must be of such level as to directly drain the hearth, leaving only about two-fifths of the charge behind for cold charging, or complete teeming when liquid charging is used.

Now, in the earlier days, a pointed steel bar was simply driven in, similar to the cupola practice, which is easy enough when the taphole is kept always "free." But, often enough, mixed slag—and steel—crusts froze in the slag hole, and considerable violence was exercised in breaking in through, which usually sooner or later led to a destruction of the lining round the taphole.

The author, therefore, adopted the practice known from carbide manufacture, to use a "live" bar, *i.e.*, a pointed steel bar is connected to one transformer terminal, having about 65 to 70 volts, while the other is suitably connected to the metal bath, a choking coil of a few turns round an iron core, or a few turns round the back member of the furnace core, acting as an auxiliary transformer, in case only high tension is available, is equally useful. Obviously the other terminal is applied to the bath by means of a steel bar. Only about 100 to 200 amp. at 40 to 60 volts, applied for a few seconds, are required to break through the most stubborn taphole with greatest ease, if a slight hammer stroke is applied at first. It is surprising to see how clean a tap can be obtained in this way without the slightest injury to the lining; the bar is not worn away to any great extent, if it is quickly withdrawn as soon as the metal begins to flow. A further advantage is that the teeming can take place in the right and desired moment, while with the old style one had to play about the taphole at times for 15 minutes or more. It may be added that this method was not, to the author's knowledge, applied to the very furnace reported on here; but it has been used by the author in other furnaces with excellent results.

Recurring to the furnace in question, the following figures from a melting campaign at random may give an idea of the actual working:

The run covered 606 hours (including drying of the lining) with 120 charges, which gave 166 tons of finished steel of highest quality, mostly tool steel, but also steel of lower carbon content. The average power consumption over the whole run, including drying and starting, was 636 units per ton finished and degasifyed steel.

Generally 2 tons were treated in the furnace, teeming 1½ tons, leaving ½ ton for restarting. Two typical runs are given here, lasting 4½ hours each. No. 1 gave a tapping of 30 cwt. and No. 2 gave 28½ cwt.:

Hour	Volts	Amperes	KW.	Cos ϕ	No.
12 NOON....	340	440	125	0.835	
1.....	344	790	195	0.716	
2.....	336	950	208	0.650	
3.....	334	1060	210	0.590	1
4.....	334	1105	212	0.573	
4:30 P.M...	Tapping 30 cwt.				
4:35 P.M...	320	340	85	0.79	
9 A.M.....	340	560	156	0.817	
10.....	345	820	205	0.720	
11.....	330	955	210	0.670	2
12.....	338	1090	228	0.621	
1 P.M.....	348	1175	250	0.610	
1-25.....	Tapping 28½ cwt.				

To the above figures may be added: In run No. 2 a slight mishap occurred, inasmuch as a certain quantity of metal was splashed into the cooling jacket through the charging of a not quite dry lump of pig iron, hence the somewhat higher ampere readings in this case. This also somewhat lowered the power factor; no remark is made about the carbon content of the steel, but it is evident from the readings that the charge in No. 1 was of a low, and that in No. 2 of a higher carbon percentage.

It should also be noted that all the instruments were subsequently found to read somewhat too high, but as a full set of calibrating instruments could not be obtained at the time, it was thought advisable to leave the readings as obtained; the actual error cannot be very great, since *all* instruments showed a plus-reading of not a great magnitude.

The theoretical efficiency of the furnace, taking the average power consumption for one campaign as above, or 606 units per ton, inclusive of heating up, stoppages, etc., works out as follows: The melting, superheating and "killing" of 1 ton of steel requires in round figures 350,000 calories; 1 kilowatt-hour being equal in round figures to 864 calories. We thus find an efficiency of

$$\frac{350{,}000}{864 \times 636} = 63.8 \text{ per cent.}$$

This is to be regarded as exceptionally good; taking a greater number of runs, and a greater variety of steel, we get an average power consumption of 720 kilowatthours.

But, as pointed out in previous reports, it would be fallacious to judge as to the merits of the process by the theoretical efficiency only; this can only be regarded as an indicator of the furnace conditions. Apart from the quality of the product, which is stated to be of very high grade, the economical results must be carefully considered.

Assuming a power cost of ½ of a penny (one cent) per kilowatthour, a figure which in many places in England is on the high side (as low as 0.35 d. or 0.7 cent has been offered, to the author's knowledge, for a load factor of over 80 per cent), we find the approximate costs to be as follows: On a furnace as the one described, giving 1½ tons every 4½ hours, or 7.95, say around 7 tons in 24 hours.

		Per Ton
Power 720 Units @ ½d.		£1.10.0.
Lining: (relining after first run):		
2 tons magnesite @ £4.10	£ 9. 0.0	
1 ton dolomite @ £1.10	1.10.0	
Tar	10.0	
Bricks	1.10.0	
Labour	3. 5.0	
	£15.15.0	
to last for say 175 tons		1.10
Labor:		
2 melters @ 8/- per day (2 shifts), 4 assistants @ 5/- per day, 1 labourer @ 4/- per day, or, per 24 hours equals 40/- and 7 tons, say		5.8
Extra labour occasionally		1.0.
Management		3.6.
Sundry expenses, daily repairs, etc		3.0.
Depreciation		2.0.
Losses 1½%, say		4.0.
Total		2.11.0.*

*Estimated melting cost per ton of steel.

If we add to this a margin of, say 10/- per ton, to cover any accidents on bad linings, general mishaps, stoppage of power, license, etc., a figure which, it must be admitted, is rather generous, we still find that the actual melting does not materially exceed the figure of £3. 0.0 per ton of steel, ready to sell.

It is generally admitted in Sheffield that the average cost of crucible melting is well up to double the above cost and generally more, taking everything into consideration.

The above figures are, of course, based on crucible steel melting only; although it may be quite possible to refine inferior raw material into high quality steel in induction furnaces of the Roechling-Rodenhauser type, as daily practice has shown, it is not intended to recommend such refining in a simple Kjellin furnace, on account of its hearth shape, which leaves only a limited area of contact between slag and steel, and also on account of the difficulty in keeping the slag blanket sufficiently hot. The furnace described was ordered as a melting machine only, to take the place of a crucible plant, capable

of executing all that is required of the latter, and experience has proved that these conditions were fulfilled, at a considerable reduction of cost, giving a steel fully up to the quality of the best crucible steel.

Luton, England.

Improvements in Smelting at the Consolidated Company's Works, Trail, B. C.

By E. Jacobs

The Consolidated Mining & Smelting Company of Canada, Ltd., continues to make improvements and additions to plant at its lead and copper-smelting works at Trail, B. C. That it is smelting a larger quantity of ore this year than last is evident from the following comparison, which shows also a generally higer value of ore smelted. During five months ended May 31, 1913, the quantity of ore and concentrates smelted was 134,660 tons, the gross value of which was $3,526,436. This compares with 296,458 tons of material smelted during the company's last fiscal year, and a gross value of $5,083,078. The monthly average of ore smelted this year was 26,932 tons, gross value $705,287, as against 24,705 tons, gross value $423,590, for last year.

Lead Smelting Department

In the lead sampling mill provision has been made for finer crushing so as to obtain a better product for roasting. Formerly the crushing was done by a Gates gyratory, one set of 42 in. by 16 in. heavy-duty Traylor rolls, and two sets of lighter rolls of the same make. Now the lighter rolls have been replaced with two sets of the heavy-duty type. Conveyor belts are being placed under all lead-ore beds. These will feed directly to the hoppers of the roasters and thus do away with the manual labor required for tramming from the beds to the roasters.

Part of the old building housing the Huntington-Heberlein sintering plant has been taken down, leaving but 175 ft. of the old structure standing. In place of the part removed, a wooden building has been erected, 61 ft. by 234 ft. The roof trusses are wood with iron tie-rods, making an excellent roof that withstands wind and rain, and carries the snows of winter. A similar roof on the company's lead refinery building has been serviceable and lasting. An electrically-operated Niles 20-ton crane is used in this building, the rails being spaced 58 ft. centers.

Seven Huntington-Heberlein roasters are in use, and preparations are well forward for putting in two Wedge roasters, early receipt of which is expected. The fire-brick to be used in their construction are now on the ground, and it is intended to have the furnaces in operation late in the ensuing autumn. In order to provide space for the roasters it was necessary to remove a large gravel bank, which was done by hydraulicking.

There has been a rearrangement of the sintering pots, of which there are 36 in the building. These have been placed in four rows of nine each, and in convenient proximity there has been erected a large concrete bin to receive the ore which has received a preliminary roast. A steel conveyor handles the roasted ore between the roasters and the bin. The sintering pots are filled from the latter and then lifted by the crane which places them on the converter stands. After the ore is properly sintered and cooled, the crane again removes the pot and dumps the contents on a floor, thus breaking the large cakes. A Hayward clam-shell bucket, the largest size made, lifts the broken sinter and dumps it into the hopper of a 24 in. by 36 in. Farrel crusher, from which it is removed to bins by a steel conveyor. At the upper end of the conveyor the sinter is passed over coarse and fine grizzlies which eliminate the fine portion and deliver a product suitable for the lead blast-furnaces. The fine part is returned to the bin and again sintered with a fresh charge of roasted ore.

A gas-producer is being installed to provide gas fuel for all the roasters, and for such other purposes for which it may be found advantageous to use producer-gas. A new building has been erected adjacent the Huntington-Heberlein building to house the small Roots blower and a centrifugal fan giving 16 oz. pressure. In the upper story of this building are an office for the shift boss, and change and lunch rooms for the men, so that they may be away from the lead dust when eating and resting.

Three new lead blast-furnaces are being constructed; dimensions at the tuyeres, 45 in. by 216 in. They have wrought-iron jackets with 14 tuyeres; also cast-iron jackets with single tuyeres, as at present in use on the old furnaces. The height from center of tuyeres to feed-floor level is 17 ft. 6 in. These new furnaces will have their feed floor on the same level as that of the copper furnaces, instead of the higher level found convenient for hand feeding. With mechanical arrangements, one level for the feed-floor of all furnaces, both copper and lead, admits of more economical handling of furnace charges. To provide room for the new furnaces, the main building has been extended eastward by the addition of another bay of about 40 ft. with a lean-to to the south. The lowering of the tapping floor of the lead furnaces 10 ft. below the former level necessitated the removal of a lot of gravel, which was done by hydraulicking it out to the dump. Meanwhile the feed tracks of the two old furnaces, which are to be taken out, and the columns of buildings, etc., had to be supported while the changes were being made and until concrete piers and I-beams were put in place to form a new foundation and substructure.

Copper Smelting Department

In the copper smelting department, the improvements in hand include a conveyor to transport ore from the copper sampling mill to a stock-pile when there is more ore coming from the mill than can be held in the furnace bins. A new storage bin has been built, with sloping sides; and underneath is a tunnel into which cars are run for the ready withdrawal of ore from the bin. All stock-pile floors and bins now have tunnels under them, so that the removal of material is greatly facilitated and shoveling is entirely abandoned.

In place of the 4-ton motors formerly used, there are now two 7-ton electric locomotives for hauling to the charge bins, and larger cars are being made. It is the intention that these improvements shall permit hauling to the charge bins being done on one shift. One of the 7-ton locomotives is used also for hauling cars of lead anodes from the tapping floor to the refinery, instead of by railway locomotive as before.

The copper smelting plant has for some time included five blast-furnaces. Of these No. 2 has been replaced by a 42 in. by 35 ft. furnace with 28 standard tuyeres on each side. This furnace has an arched top and flat flue, the latter arrangement permitting the elimination of the goosenecks and the use of an overhead traveling crane on both furnace floors. It is expected that the new furnace will be found to possess such advantages that two similar furnaces, each of 450 tons daily capacity, will be substituted for three smaller furnaces, thus providing for the daily treatment of 1350 tons of ore, excluding fluxes, in three blast-furnaces.

On the new No. 2 furnace the feed-water pipes have been so arranged that all valves can be reached from the tapping floor, and discharge pipes so placed that the furnace-man can at all times see that waste water is coming from the jackets. The overflow trough has been made larger and placed farther out, so that no water will spill on the furnace-man when engaged in punching tuyeres.

The new furnace has center feed, the charge train being pushed into it by the electric motor. At present the cars run into the furnace on water-cooled rails on the track level; but after the tunnels under the charge bins shall have been enlarged wheels will be placed on the upper part of the charge cars and the latter will then run into the furnaces on rails placed at the proper height.

Crushing and granulating of copper matte is no longer done here as formerly, and the old plant used for that purpose has been taken out. This gives more room at the west end of the

furnace floor and permits a rearrangement of the tracks about No. 1 furnace. All low-grade copper matte is put through this furnace with silicious ore to raise the copper content and give a matte of 35 to 40 per cent copper. This product is shipped to works at Tacoma, Wash., for converting.

No copper-ore roasting is now done at Trail in the Huntington-Heberlein pots. Copper concentrates only, chiefly from the Rossland mines, are sintered on the Dwight & Lloyd machines. The gates of the latter have been changed from the herringbone type previously used to straight-slot self-cleaning grates.

Blast is delivered to the furnaces at 32 to 34 oz. pressure. Six blowers have been in use, four Roots and two Connersville. Another No. 11 Roots is being added to give 401 cu. ft. per revolution. It will be driven by two 300-hp induction motors.

The pyritic smelting of raw copper matte commenced in the early part of 1912 has been discontinued at Trail. While this practice was followed the charge consisted of 4200 lb. matte, 2000 lb. silicious ore, 13.5 per cent lime rock and 4 per cent Crow's Nest coke.

The ore now treated in the copper smelting department is obtained chiefly from the company's mines at Rossland. An approximate analysis of the ore shows: iron, 17 per cent; silica, 44 per cent; lime, 5.5 per cent; alumina, 15.5 per cent; sulphur, 8 per cent; magnesia, 3.5 per cent. This ore is smelted with 30 per cent lime rock and 16 per cent Crow's Nest coke.

Colorado School of Mines

The institution opens September 2 for its thirty-ninth annual session. The Summer school, held during July and August, had an attendance in excess of last year. This session offers the best opportunity for conditioned students to remove all obstacles to complete standing; and applicants for advanced standing, who are rarely prepared in every study, may also use the Summer school for completion of their requirements.

The expected registration at the School of Mines proper is 240, chances for a greater number depending on unforeseen admission to advanced standing. The graduation of seventy young men last May illustrates to what an extent in recent years these admissions have served to swell the numbers in the upper classes.

The working schedules of the institution have been largely revised during the Summer. The changes are all in the direction of greater simplicity in the courses. This has been accomplished without any material sacrifice of topics, nothing essential having been omitted in the new arrangement.

Mr. Harry J. Wolf, who acted as professor of mining during a part of last year, has accepted the position permanently for the coming year. The headships of all other departments remain as before. The total number in faculty, including associates and assistants, is twenty-four.

Ancient Egyptian Metal Objects

In a paper read at the recent meeting of the (British) Institute of Metals in Ghent, Belgium, entitled "Metallographical Researches on Egyptian Metal Antiquities," Mr. **H. Garland** describes his investigations into the crystal structure of Egyptian metal objects, all more than 2000 years old, made either of bronze or copper.

He gives the interesting case of a bronze knife 3500 years old in which the original cored structure has endured until the present day and is still perfectly stable at atmospheric temperatures. The view is held that the knife was hammered cold and so the best cutting edge was obtained. The crystal grains are very small, there having been apparently no crystal growth during the ages that have passed since the metal was first worked. This shows either that recrystallization does not take place at ordinary temperatures or if it does, then many times 3500 years is required to effect the change.

Mr. Garland, in his paper, gives other cases of the persistence of the "cast cored" structure in antique alloys, illustrating his views by means of photomicrographs of a small bronze chisel, such as would be used by a jeweler in ancient Egypt, a copper arrow tip and of a bronze spatula.

An interesting photograph reproduced in the paper is of a Roman coin which still shows cores, though, as has been stated by Dr. Rose, of the Royal Mint, such coins were struck hot. Mr. Garland holds that the heat could only have been slight, otherwise the cored structure would not persist.

Electric Furnaces—Their Design, Characteristics and Commercial Applications

By Woolsey McA. Johnson and George N. Sieger

Specific Design and Important Details

Electrodes.—To the electric furnace there come two conductors from the source of power; these lead to the electrodes (electrodes is a word derived from the Greek at the instance of Faraday from the words electra, electricity and hodos, path) and by these electrodes the electric current is delivered to the laboratory or working space of the furnace.

The electrodes must conduct electricity fairly well but should not conduct heat very well. Such a material does not exist, for every conductor of electricity is a conductor of heat, and quantitatively the two properties vary together and hence must be considered together in design. The two qualities, one good and one bad, must be made the subject of mutual adjustment.

By designing the electrodes of proper dimensions, it is possible to have an electrode that will conduct electricity with a minimum of loss and will conduct out a minimum of heat. This condition is not obtained by the ordinary current density design for in this design larger electrodes will run hotter than small ones owing to the fact that in the case of the larger electrodes the interior area has no chance to radiate its heat whereas in the smaller electrodes this is not the case. A much better principle of electrode design than that of current density is to keep the radiation surface constant per unit of current. The condition for minimum electrode loss is that when the temperature of the electrode is the temperature of the interior of the furnace the electrode will abstract no heat from the furnace.[1]

Electric furnace electrodes can be made of the following materials:

(1) Acheson graphite.
(2) Molded carbon.
(3) Metals such as copper or steel.

Practical Information about Electrodes

	Electrical Resistivity c. g. s.	Thermal Resistivity c. g. s.	Safe Carrying Capacity in amp. per sq. in.
Acheson graphite	0.000813	6.18	125
National Carbon Co.'s molded carbon.....	0.0038	61.8	38
Steel or iron.....	0.000009652	6.25	170
Copper	0.00000165	1.22	1000

Safe carrying capacity in amperes per square inch:

	Acheson Graphite	National Carbon
5" round	2350	720
6" "	3500	1000
8" "	6300	1900
10" "	9800	2900
12" "	14,100	4300
14" "	19,300	5850
16" "	25,000	7625
2" square	600	150
4" "	2000	600
6" "	4500	1350
8" "	8000	2430
10" "	12,500	3800
12" "	18,000	5450
14" "	24,500	7450

[1]Carl Hering, Transactions Am. El. Chem. Soc., vol. 16, p. 265, 1909; E. F. Roeber, Transactions, vol. 16, p. 363, 1909.

	Voltage drop per foot at safe carrying capacity		RI[2] loss per foot length at safe carrying capacity (KW)	
		National		National
	Acheson	Carbon	Acheson	Carbon
5″ round	0.49	0.68	1.14	0.48
6″ "	0.47	0.64	1.64	0.64
8″ "	0.44	0.665	2.77	1.26
10″ "	0.48	0.636	4.70	1.84
12″ "	0.42	0.645	5.90	2.77
2″ square	0.58	0.68	0.35	0.10
4″ "	0.48	0.60	0.96	0.36
6″ "	0.45	0.68	2.02	0.91
8″ "	0.48	0.68	3.84	1.65
10″ "	0.51	0.68	6.35	2.37
12″ "	0.36	0.70	6.48	3.85

Steel or copper electrodes are rarely used save for the bottom electrode of a furnace having a bath of metal. They must be water-cooled either by a spray or by a waterjacket. Usually it is well to design them at safe current-carrying capacity for cable or bus-bar, that of 1000 amperes per square inch of copper and 170 amperes per square inch of iron or steel. But 3000 amperes per square inch of copper and 500 amperes per square inch of iron and steel is permissible provided the electrode is well water-cooled.

Carbon electrodes of small sizes are made out of crushed petroleum coke or of anthracite slack in larger sizes mixed with one or several kinds of tar as a binder. Probably the best tar is gas-house tar containing carbon in a form similar to lamp black, in suspension.

A hot mixture of this is poured, molded, or extruded into the desired form. The green electrodes are slowly heated progressively, finally reaching a white heat. They are covered in the open-hearth furnace in which they are heated with sand to prevent oxidation. The temperature must be lowered slowly. Indeed, it is the practice at a certain German works to keep up the heat allowing the temperature to retrogress slowly.

As considerable gas is evolved in the process through the pores of the electrode and as the resultant product must possess a firm, hard structure, it is easy to see that this heating and cooling must be slow and uniform.

For an electrode of large cross-section such as is used in a Cowles type of furnace, a wooden form can be filled with hot "electrode concrete-mixture," made by mixing broken *irregularly sized* pieces of electrodes, fine dust and tar and tamping same hot into place. A long needle is run through so as to make holes spaced every 1 in. or 2 in. in order to allow the gases to escape easily. Then a wood fire is built and when the mass is dried out, the final cementizing carbonization is effected by passing an electric current through the mass.

Graphite Versus Amorphous Carbon Electrodes.

Graphite electrodes are made by the Acheson process by subjecting molded amorphous carbon electrodes in an electric furnace to a heat sufficient to graphitize the carbon, say, from 2300 deg. C. to 2500 deg. C.

The commercial comparison of Acheson graphite and amorphous carbon is interesting. The cost of Acheson graphite electrodes is from 11 cents to 16 cents per pound while carbon electrodes sell in this country for from 3½ cents to 6½ cents per pound, prices of each varying with size of order and shape of goods.

Both are resistant to oxidation, for the carbon is so molecularly dense[2] that it has but a slow affinity for oxygen. As most electric furnaces have a neutral or reducing atmosphere the oxidizing of the electrodes by the oxides of the charge is not great. There is, of course, a slight regular consumption of both. The writers cannot find that for rated loading, graphite electrodes are more resistant or oxidizing influences of the continuous zinc furnace than is the amorphous carbon electrode.

[2]A comparison of activity of carbon can be made by studying the reduction temperatures of different forms of carbon. See W. McA. Johnson, Bulletin Am. Inst. of Mining Engineers, Aug., 1913, "Reductivity of Metallic Oxides as Affected by Heat Treatment."

Acheson graphite, however, tends to increase the heat losses of an electric furnace unless conditions are such that they can be loaded up so that the heat generated in them is such that they are hot clear to where they protrude through the furnace roof.

As the Acheson graphite electrodes have been subjected to a second heating and annealing process, any electrode with small or concealed "check" has been passed to the scrap heap. As the heat conductivity is higher they are more resistant to the sudden changes in temperature than are the amorphous carbon product.

Both kinds of electrodes can be machined but the Acheson graphite much more readily and exactly.[3] The ordinary metal-working or wood-working tools can be used to machine either sort of electrodes. They will turn down easier than brass or bronze and in the case of Acheson graphite the machine is always operated at highest speed. It has been found that the best joint suitable for electric furnace needs is made by using a cylindrical threaded plug (Fig. 1). This is screwed equal distances into the ends of the electrodes to be joined.

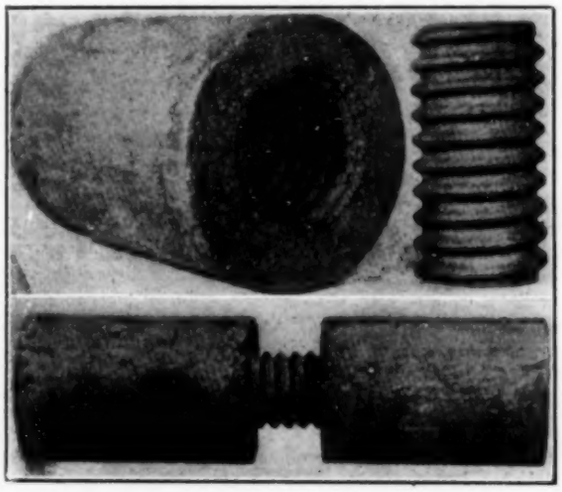


FIG. 1.—JOINING CARBON ELECTRODES

When joined electrodes are used care must be exercised so as to obtain good electrical contact, thus preventing the joint from becoming overheated. By the use of joined electrodes the expensive and wasteful butt ends are eliminated, but only round electrodes can be used for this operation.

Where a furnace working is made more difficult by the lowering of temperature in spots amorphous carbon is superior to artificial graphite.

For most purposes the present difference in price is such as to favor the use of amorphous carbon electrodes. In many places a price ratio of one to two and one-half about equals the value ratio of services of each commodity to user.

A practical smelting furnace should always be made with means to "fish" and pull out a broken stub electrode, through a side door.

Where necessary, electrodes can be sheathed by a tinsmith with sheet steel or copper so as to resist oxidation at spots where they protrude from the furnace. If a bedding is made in thick walls they will not be hot enough to burn at this point. Water-cooling can well be employed in this connection.

Square electrodes or those rectangular in cross-section are preferable in any furnace where the electrodes are permanently fixed, such as the Bailey bar-heating furnace, because of ease of laying in conformity with the courses of brick to round electrodes. Round electrodes are preferable to square electrodes in a steel-refining furnace or a furnace of the buried arc type such as is used in the manufacture of calcium carbide.

Summing up the practical knowlege about the electrode problem, it can be said that the electrodes should be designed as large as possible in order to have an excess carrying capacity

[3]International Acheson Graphite Co. Bulletin No. 6. C. L. Collens, Trans. American Electrochemical Soc'y, vol. 1, p. 53, 1902; W. McA. Johnson, Electrochemical Industry, Sept., 1904, p. 345.

for the periods when the furnace requires more power than during normal running conditions. But this size should be limited by the amount of cooling done to the "laboratory" of the furnace; also that a number of small electrodes is usually better in a smelting furnace than one or two large ones.

ELECTRODE CONSUMPTION AND ACCESSORIES

Electrode consumption is of two kinds, that lost in the "laboratory" of the furnace by accidental oxidation or incidental oxidation from the oxides in the charge or gases and that

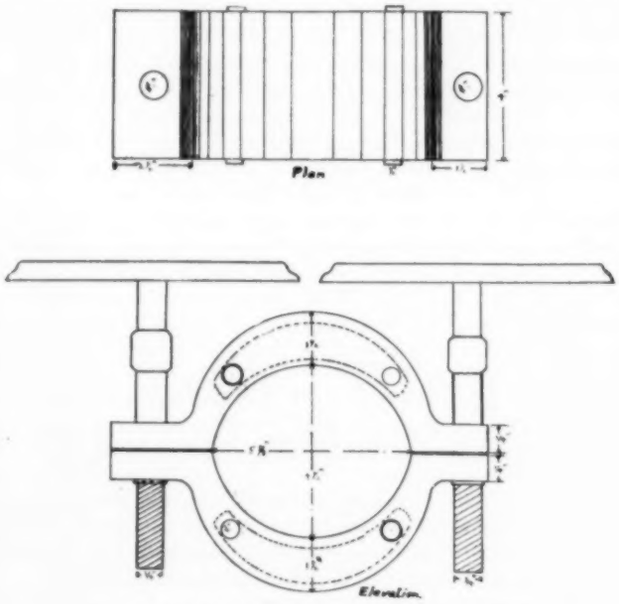


FIG. 2.—WATERCOOLED ELECTRODE HOLDER

lost by breakage or by reason of non-utilization of stub ends. As both amorphous carbon and graphite are much more chemically resistant to oxygen than carbon of coke, coal or charcoal of the charge used in the electric smelting furnace the loss by oxidation rarely amounts to more than 30 pounds per ton of primary raw material and often is less than 10 pounds. In steel furnaces of the Siemens type the total electrode consumption is often less than 25 pounds per ton of finished steel.

Electrode loss by reason of non-utilizable stub ends can be reduced to a minimum by using *round* electrodes and joining them together as heretofore described. When electrodes are thus joined they are slowly and continuously fed into the furnace at the rate at which they are consumed.

Electrodes can be placed in the furnace in all ways, horizontal, inclined much or little from the vertical, and vertical. Where the *slightest necessity exists,* they should be water-cooled, on connection clamps.

When all the above considerations are in the mind of the designer and when proper distribution of controlling factors of design is made, electrodes are relatively simple parts of electric furnaces. What is important is what goes on between the ends of the electrically opposite electrodes. When the metallurgy of the process is firmly and clearly understood, the electrode problem solves itself.

Where a movable electrode enters the furnace, something resembling a stuffing box must be provided. In an experimental furnace this can simply be proper cutting out of the brick or a form made out of No. 22 or 20 galvanized sheet steel made by a tinsmith and filled in with plastic fire cement.

For high temperature work a stuffing box of Acheson graphite is recommended. For regular operation the stuffing box had best be built of special shape fire bricks made by firebrick manufacturers, or a cast iron, cast steel, or water-cooled cast "composition" metal (a mixture of 95 per cent copper, 4 per cent zinc, 1 per cent tin is recommended) stuffing box used. The cast iron and cast steel stuffing boxes can be advantageously water-cooled.

The taper of the stuffing boxes should be from ⅜ in. to 1¼ in. to the foot. The clearance at the lower end should be from ⅜ in. to 1 in. Where a gas-tight joint is desired, ¼ in. to 1/3 in. asbestos rope can be wound about the electrode or stuffed into the box. (The Continuous Zinc Furnace Co. uses with satisfaction that asbestos fiber made by Johns Pratt Co.) No. 688 ranging from 7/32 to ¼ in. in diameter. Mineral wool, graphite, coal dust, fireclay or sand can be poured into fill up the interstices.

With the exercise of a little care and common sense a practical stuffing box for the low pressure existing in the electric furnace is quite easy to design provided some practical experience has been available.

The terminal connection of a small furnace electrode can be either a copper plate bolted or clamped to the flat surfaces of the electrode. In the case of a round electrode a portion of the electrode is cut off making a flat surface. The connection to the line is made through an air cooler. The air cooler consists of several pieces of sheet copper, say, a half dozen of sufficient width so as to be of proper carrying capacity, the sheets being soldered together at both ends. The central portions, for about six inches, are separated from each other so as to permit air currents to pass between them. The air cooler is about eight inches long, the one end being bolted to the main the other either bolted or clamped by an ordinary malleable iron carpenter's clamp. The purpose of the air cooler is to insure the solder of the terminal lug from melting. The use of a clamp is desirable for should the contact become poor an 8 in. monkey wrench applied to the thumb flanges will remedy matters.

In any large furnace or experimental furnace where runs of over two days are made a bronze terminal connection with a piece of copper gauze between the terminal connection and electrode is the proper thing. The alloy used for this is "ounce" metal copper 85 parts, zinc 5 parts, lead 5 parts, tin 5 parts.

The form used by the Continuous Zinc Furnace Co. is shown

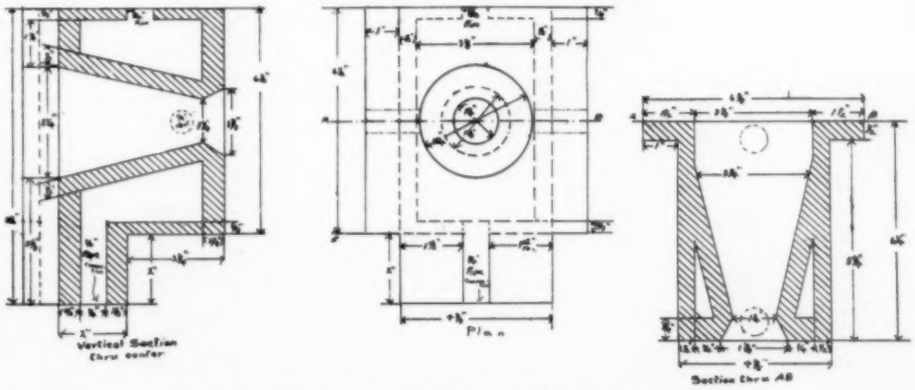


FIG. 3.—CINDER MONKEY OF CONTINUOUS ZINC FURNACE CO.

in Fig. 2. It consists of a connection built up of two exactly similar portions which when closed are just a trifle elliptical in shape to insure a firm hold on the round electrode. The portions can be hinged together and secured by means of a bolt or by two bolts as shown. Water-cooling connection from one portion to the other is provided by means of rubber tubing, or ⅜-in. piping. Mr. C. A. Hansen, of the General Electric Co., is an advocate of the use of wedges for tightening contact which is an easy and practical way, for the furnaceman can use a brick bat if a hammer is not handy.

Terminal connections should be "over designed." From 5 to 10 amperes per square inch of contact surface, is the authors' recommended figure.

Tap Holes

In an electric furnace of the stationary type as compared with the tilting, producing a molten product, provision must be made for removing this product from the furnace. In the

FIG. 4.—BRONZE CINDER MONKEY

tilting furnace this problem is solved, by tilting the furnace and simply pouring at will part or all of the fluid contents.

Some sort of a tap-hole must be made in stationary furnaces. Electric furnace processes follow ordinary processes of furnace tapping.

For slags and metals or metal products that do not attack copper such as copper matte, a water-cooled tap-jacket is decidedly the best. The illustrations give three types of tap-jackets. Fig. 3 shows the one now used by the Continuous Zinc Furnace Co.; the other, Fig. 4, is a standard tap-jacket or "cinder-monkey."

The "cinder or slag monkey" can be set in a "monkey-house." Fig. 5 shows the design of a monkey house for "monkey" shown in Fig. 3. It is made of cast iron, proved to be serviceable and cheap.

All water-cooled "monkeys" should have a good flow of water through them more especially during a tap. *The water must enter at the bottom and come out at the top*, otherwise pockets of live steam are formed and the "monkey" will burn out.

"Monkeys" can be made of an alloy 95 per cent. copper, 5 per cent spelter, or of 98 per cent copper and 2 per cent tin. Both aloys work satisfactorily.

Stopping the Flowing of Slag

The flow of slag can be quickly stopped by inserting a tapered bar or a "dolly bar" ¼ in. larger than the diameter of the aperture through which the slag flows or by a clay "bott" on a botting bar. The botting bar consists of a disc 2½ in. to 3½ in. in diameter, the disc being ½ in. thick. This is screwed to a ¾ in. gas pipe and can be made any length.

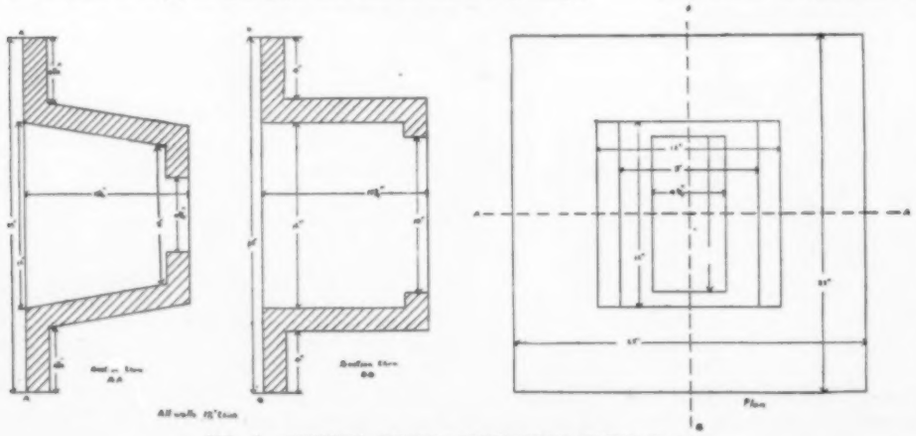


FIG. 5.—MONKEY HOUSE, CONTINUOUS FURNACE CO.

In case the slag buggy or ladle be placed in front of the tap hole as in the case of an experimental furnace the bars should be at least 9 ft. in length so that the furnace man can have a chance to reach over the ladle without having to stand too close to the ladle. A small "teat" or projection about an inch long is attached to the face of the disc so as to hold the bott of clay in place.

The clay bott is best made conical in shape, the base being somewhat larger than the face of the bar, and tapered so as to fit the taper of the slag monkey used. The bar is best moistened so that the bott will stick to it while being put into the monkey.

The furnaceman stopping the flow of the hot metallurgical liquid with either the iron bar or the conical clay bott should have an idea of where the slag hole is relative to where he is standing by co-ordinate sense of mind and body since he is partially blinded by heat. He should stand unanxious and unafraid with muscles and nerves relaxed.

When sufficient material has been tapped he should quickly apply his bar or bott to the "monkey" turning his face away so as to prevent the "sparks," if any, from burning him. These "sparks" are caused by the superficial moisture in the case of the clay bott being turned instantly into steam and are practically unnoticeable when an iron bar without bott is used. Three light taps of the sledge by a fellow workman complete the job. If possible there should be a stand for the workman on a level with the tap hole. By this means the workman looks down and is in a position to see the flow of the hot liquid. Also an iron bar transverse to flow of liquid is a good thing for it allows the workman to rest his botting bar previous to the final insertion.

The amateur had best wear a wide brimmed soft hat, goggles, woolen clothes including a high necked sweater, and leather gloves with gauntlets. (An old fencing mask is ideal for protecting the face and eyes.)

The clay mixture of which the "bott" is made consists of 4 parts crushed firebrick and 6 parts plastic fire-clay well worked up with water to a stiff mud. J. H. Gautier & Co., Jersey City, supply this material in barrels at a reasonable rate and it is better business for a small consumer, such as an experimental station, to buy such material from a manufacturer than to attempt to make it.

Tap-holes can be made of this material in a manner similar to the tap-holes used in the iron foundries, but they are not certain when used with slags or mattes while the water-cooled tap-holes made of metal can not be cut by slags when the water is turned on full. For metals such as steel, copper, lead, etc., a well built tap-hole of fire-clay or other refractory is the thing.

A good temporary tap-hole can be made of a stub graphite electrode or of an old carbon electrode. However, it cannot be drilled into.

Getting into the Furnace

Getting into a furnace is usually an easy matter. A steel drill bar is driven into the tap-hole by the use of a 14 to 18 pound sledge hammer. The bar is best made of ⅞ in. or 1 ft. octagon stuff about 6 ft. long. The end is drawn out to a drill-end as in a wall drill used by electricians so as to give a drilling effect. The "jabbing bar" used to break through the outer crust after a hole has been drilled, till a red color shows, should simply be pointed. When the tap-hole once shows a dull red a bar without much temper will be found satisfactory since it would not retain its temper any length of time under these conditions.

Should the bar stick upon attempting to remove it a "puller" will be found indispensable. The "puller" consists of a heavy piece of iron cut out so that it will just clear the sides of the bar upon which it is to be used. A second piece of wedge-shaped iron is inserted between the first piece of iron and the bar and tapped with a hammer. The "puller" should be made of at least inch stuff.

However, should the contents of the furnace be frozen about

the tap-hole it is clearly impossible to drive the bar in and the furnace must be heated up by putting in an extra amount of power for some time or a hole "arced in" by the use of an auxiliary movable electrode until a bright red is seen when an attempt should be made to drive the tap-bar.

But generally, the proper way is to see that the furnace is well heated and the lower contents liquid. The proper way to get stuff out of a furnace and how best to stop it up can only be learned by experience although the above hints will prove to be helpful as they are based on good theory and on good practice.

In the next article, the authors will deal with the ironing of an electric furnace, with water-cooling, with refractories, with feeds, and other important details and parts of electric furnaces.

Erratum.—We wish to make a correction of an error in the first article published in the last issue of this journal. An average coal with a heating value of 11,150 b.t.u. per pound (instead of 11,600 b.t.u. per pound) contains exactly the same heat as a horsepower year.

The Quantitative Determination of the Precious Metals—Gold, Silver and Platinum*

By Trenkner,
Assistant Assayer, Royal Mint, Berlin

Since the rise in the price of platinum the assay of coins and other alloys of the precious metals has needed considerable modification. The platinum alloys required a very high temperature in cupellation, causing a great loss of the precious metals. The button contained lead in varying amounts; it was brittle and could not be rolled in the usual way.

The platinum when alloyed with silver dissolved in nitric acid with a brown color, though not completely, while the residue fell to a fine powder which was hard to gather and did not agglomerate when heated, thus making direct weighing impossible.

The French Mint in Paris published in its annual report of 1901 its experience. The account showed, however, that the difficulties had not been surmounted.

According to the instructions of the Direction Générale des Contributions Indirectes of June 8, 1910, platinum in gold can only be determined with an accuracy of 10/1000 (or 1 per cent) and the error permitted by law for platinum was, therefore, fixed at 10/1000 (10 millimes).

In the following article a method will be described which allows of the determination of platinum and gold with an accuracy of 0.5/1000, or 0.05 per cent; with more extended experience a still greater accuracy may be reached.

With alloys containing more than 250/1000 gold plus platinum 500 mg. = 1000 A.T. (assay tons) are weighed out; with alloys containing less gold and platinum 1000 mg. = 1000 A.T. are weighed out.

For a preliminary assay the material is disintegrated by hammering and rolling. It is better to use granulations than cuttings obtained with the chisel, since platinum bars show considerable variation; it is also advisable to add silver to facilitate melting and to obtain a homogeneous alloy. Five hundred A.T. of this material are cupelled at a temperature of 900° to 950° C., with an addition of 3 to 15 g. of lead, according to the amount of base metal present. The button always retains some base metal, mainly consisting of lead. With large amounts of platinum present the button weighs more than the weighed out portion, due to the lead retained.

From the appearance of the button its content of platinum and gold may be estimated with some experience. If this fails, the button is treated in the manner described later, but without the caution which is required later on by putting the button into concentrated sulphuric acid, thereby dissolving the silver. The remaining gold and platinum is weighed.

In the regular assay 500 A.T. (generally in duplicate) are weighed out and chemically pure silver is added, making the proportion of silver to platinum plus gold equal to 10 to 1. This is cupelled with the necessary amount of lead and after deducting the amount of silver added the total amount of silver plus gold plus platinum is obtained by weighing the button.

The loss in cupellation may amount to 5 to 35 A.T.; it depends on the temperature, the amount of lead used, the time of cupellation, the kind of cupel used, the amount of silver present, and the composition of the alloy. This loss must be determined by experiments with alloys of varying composition. More accurate results are obtained by cupelling simultaneously a check assay of approximately the same composition as the one to be assayed.

The alloying with silver has the following advantages: The button is free from lead (see Sharwood, Cupellation of Platinum Alloys Containing Gold and Silver, Jour. Soc. Chem. Ind., Vol. 23, p. 412, 1904), it is easily removed from the cupel and no appreciable amount of gold and platinum is lost by this cupellation, because this loss diminishes with the increase of the silver.

The button is put into a parting flask containing 25 c.c. concentrated sulphuric acid of 1.84 specific gravity; the button is neither hammered nor rolled.

The acid is heated with a round burner without boiling, avoiding uneven heating or overheating. The silver dissolves in from twenty-five to thirty minutes. The residue of platinum, gold and small amounts of silver always retains its coherence, which prevents mechanical losses on decanting. When the acid is heated to boiling considerable bumping takes place; this, however, does not cause the complete dissolution of the silver even when the acid is renewed. Furthermore, platinum is soluble in boiling concentrated sulphuric acid and boiling causes, therefore, a loss of platinum. After cooling somewhat, the acid is decanted carefully and the residue washed three times with boiling water; the wash water is conveniently passed through a filter. The residue in the flask is put into a porcelain crucible in the usual manner, by filling with water and tilting, and is then annealed together with the filter in front of the muffle.

In this way an addition of gold is avoided, also rolling and the making of cornets. The residue always retains its coherence. Cornets under similar circumstances retain their coherence only within very narrow limits so that the amount of platinum plus gold must be fairly well known beforehand.

The residue is dissolved in the smallest quantity possible of aqua regia, the free acid is evaporated as much as possible, and diluted with distilled water. The chloride of silver is filtered. We have now a solution of about 150 cc. containing platinum and gold.

The best and most convenient reduction reagent for the gold is "hydrazin hydrochlorid." It sometimes carries down some platinum (compare Jannasch and Mayer, Ber. d.d. chem. Ges., Vol. 38, p. 2129, 1905); but it is still the best method if certain conditions are observed. Its power of reduction is decreased by an excess of hydrochloric acid and when working at low temperatures.

The gold is precipitated in the solution after adding 15 cc. hydrochloric acid (1.19 specific gravity) and about 1 g. hydrazin hydrochloride. The solution is left standing at 18° to 20° C. for one hour, with occasional stirring, which causes the gold to agglomerate.

After filtering, incinerating, and annealing, the gold is weighed directly (without the crucible). The gold which frequently contains some platinum is melted with a little lead and five to eight times its amount of silver in a cupel in the muffle and then parted with nitric acid, thus dissolving the silver and any platinum that might be present. The remainder is gold.

In the filtrate from the precipitated gold the platinum is precipitated by boiling with an excess of ammonia in about ten minutes (compare Jannasch, Ber. d.d. chem. Ges., Vol. 37, p. 1980, 1904). If the platinum contents are low it is better to evaporate most of the hydrochloric acid present by gentle boiling, as ammonium chlorid in great excess prevents the pre-

*Translated from *Metallurgie*, vol. 9, p. 103 (1912) by A. F. Fuerst.

cipitation of platinum through the formation of complex ions. The platinum may also be precipitated by caustic potash or caustic potash and ammonia, in which case, however, the filter has to be washed very carefully with water containing hydrochloric acid. The platinum may then be weighed directly (without crucible), after incineration and annealing.

In order to show that the gold is precipated quantitatively under the conditions given the following experiments were made:

(1) 500 A.T. of gold (1000 A.T. = ½ g.) are disolved in aqua regia and most of the acid evaporated, diluted to 150 cc., 10 cc. hydrochloric acid (1.19) and about 1 g. hydrazin hydrochlorid added, left standing at 18° to 20° C. for one hour, gave exactly 500 parts of gold.

(2) The same conditions, but with addition of 15 cc. hydrochloric acid, 499.7 Au.

(3) 20 cc. hydrochloric acid, 499.8 Au.

(4) 25 cc. hydrochloric acid, 499.5 Au.

(5) 20 cc. hydrochloric acid, 12° to 13° C., 498.8 Au.

(6) 1.5 cc. hydrochloric acid, 12° to 13° C., 499.8 Au.

In experiments (4) and (5)—0.5 and 1.2 parts were not precipitated respectively, while in the other experiments the results are within the limits of error.

(7) 500 pts. Pt, 1 pt. Au, 15 cc. CHl, 1 hour at 18° C., gave 3 pts. of gold containing platinum, which after treatment with nitric acid gave 1 pt. Au and 500 pts. Pt.

(8) 120 pts. Au, 5 pts. Pt, 15 cc. HCl, 1 hour at 18° C., gave 120.2 pts. Au and 5.0 pts. Pt.

(9) 300 pts. Au, 200 pts. Pt, 15 cc. HCl, 1 hour at 23° C., gave 303.1 pts. Au containing platinum, which after melting with silver and parting gave 299.6 Au and 200.4 Pt.

(10) 300 pts. Au, 200 pts. Pt, 15 cc. HCl, 1 hour at 18° C., gave 302.2 pts. Au containing Pt, after alloying with silver and parting 300.1 Au and 200.2 Pt.

Check asays:

(1) Weighed 120 A.T. (1000 A.T. = 1 g.) Au; 5 pts. Pt; 370 pts. Ag; 5 pts Cu. Cupelled with 1000 parts Ag and 3 g. lead. The button weighed 1489 A.T., loss in silver 6 A.T. Precipitated with hydrazin hydrochlorid gave 120.2 Au and 5 Pt.

(2) 5 A.T. Au (1000 A.T. = 1 g.); 5 A.T. Pt; 345 A.T. Ag; 245 A.T. Cu. Cupelled with 8 g. lead, gave 250 Ag + Au + Pt; loss in silver therefore 5 A. At 18° C. 15 cc. HCl, etc., gave 4.8 pts. Au and 5.3 pts. Pt.

(3) 100 A.T. Au (1000 A.T. = ½ g.); 100 A.T. Pt; 50 Ag; 250 Cu. Cupelled with 8 g. lead, after adding 2000 Ag gave 2218 Ag + Pt + Au. Loss in silver, 32 parts. Precipitated at 18° C., etc., gave 103.2 Au containing Pt, which after alloying and parting gave 99.6 Au and 100.2 pts. Pt.

(4) 50 A.T. Au (1000 A.T. = 1 g.); 50 Pt; 20 ag; 380 Cu. Cupelled with 1000 Ag and 10 grs. lead gave 1104, showing a loss in silver of 16 A.T. Precipitated at 18° C., etc., gave 52.4 Au containing Pt, which after treatment with nitric acid gave 50 Au and 50.2 Pt.

The assay of ores and by-products is carried out by scorification or by the crucible method and subsequent treatment of the regulus by the method described.

Volume Changes in Alloys

In a recent paper before the (British) Institute of Metals **Mr. J. H. Chamberlain** discusses this subject.

The results of the research show that volume changes obtained in alloys are of both theoretical and practical importance. Their relation to the crystallization intervals as plotted from the equilibrium diagram was clearly shown in the copper aluminimum series. The force producing the expansions, obtained in castings during solidification, was in the case of a copper-tin alloy (90 per cent. copper), a copper-zinc alloy (15 per cent. zinc), and pure aluminium shown to be quite considerable.

With the copper-tin alloys, and pure aluminium castings, the temperature at which the metal is poured appears to have some effect on the expansions observed. The extraordinary large and quiet expansions peculiar to the copper-zinc alloy in the neighborhood of 15 per cent copper, are always preceded by an arrest; the expansion only taking place during the crystallization of the *e* variety; microscopic examination and density experiments revealed cavieties round the crystal boundaries of this alloy, and these are produced by the absorption of *d* by *e* crystals.

On slowly heating up bars of a copper-tin alloy (90 per cent. copper), a copper-zinc alloy (15 per cent. copper), and pure aluminium in the electric furnace, contractions in the length of the bar were obtained in each case. On allowing the bar of the copper-zinc alloy to cool slowly a most extraordinary expansion was obtained, far larger than that yielded on casting, and on repeating the heating-up and cooling-down operations five times the bar was found to have grown in length from 10 inches to 11½ inches, and also to have increased in sectional area. The author is of the opinion that the contraction of the copper-zinc alloy when slowly heated may be due to the liquidation of *e* crystals, the liquid filling up the cracks existing in the casting, the skeleton crystals left intertwining. The large expansion and the continued growth of the bar on repeated heatings may be due to this filling up of the cavities, followed by the crystalline change from *d* into *e*. With the copper-tin alloy (90 per cent. copper) the expansion is apparently produced by the chilling of the liquid round alpha dendrites, since it is not observed when once the bar has been annealed. With aluminium the volume changes observed on heating and cooling are probably due to the presence of some gaseous impurity.

Phosphorus in Copper—Aluminium Alloys

A recent paper read by Professor **A. A. Read** before the (British) Institute of Metals discusses the influence of phosphorus on some copper-aluminium alloys.

Some mechanical and physical properties of a number of copper-aluminium alloys with 5 or 10 per cent. of aluminium and varying amounts of phosphorus have been investigated. The effect of small quantities of phosphorus, up to 0.2 per cent., on the 5 per cent aluminium alloy is to diminish its capacity for hot rolling, though its behavior in cold drawing is improved. The yield point and maximum stress of the annealed metals are slightly raised, and the reduction of area is lowered without, however, affecting the elongation. The resistance to alternating stress is slightly increased. Tested in the form of chill castings with varying amounts of phosphorus, up to 1 per cent., the yield point was found to rise considerably; the ultimate stress attained a maximum at 0.52 per cent., but the elongation and reduction of area fell rapidly. Phosphorus has a hardening effect above 0.25 per cent.

The 10 per cent aluminium alloy suffers considerable loss in its mechanical properties by annealing; 0.1 per cent. of phosphorus slightly improves the character of the annealed metal. There is, however, no improvement in the properties of the cold drawn metal or of the chill castings.

Phosphorus cannot be added to this metal in greater amount than about 0.2 per cent. on account of the formation of aluminium phosphide, which gives off phosphine on exposure to the moisture of the atmosphere. Phosphorus lowers the melting point and conductivity for electricity of both the alloys. When present in the rolled metal it reduces the loss due to corrosion of these alloys by sea-water. The presence of phosphorus up to 0.11 per cent. does not affect the characteristic alpha and beta structure of the 10 per cent aluminium alloy. Above about 0.2 per cent., however, the cast metal shows specks of phosphide in the beta constituent. The phosphorus in the cast alloys containing 5 per cent of aluminium separates out as a phosphide in the boundaries of the crystals of the alpha constituent. On annealing these boundaries ball up, and if less than 0.25 per cent. of phosphorus be present the phosphide passes completely into solution. The structure of the annealed and cold drawn metals, with 0.2 per cent. of phosphorus and under, is precisely similar to that of the pure 5 per cent aluminium alloy, except that the alpha constituent containing phosphorus assumes a deep bronze color on etching with an acid solution of ferric chloride.

Colorado Meeting of the American Electrochemical Society

THE twenty-fourth general meeting of the American Electrochemical Society, held during the week of Sept. 8, at Denver, Boulder, and Golden, Colo., with a final session on top of Pike's Peak and an excursion to Cripple Creek, was the first meeting of the society west of Chicago and will forever be remembered as a most successful and lively meeting. It will be remembered for the most interesting and lively discussions in the technical sessions, for the equally spirited and enjoyable social and sight-seeing functions, and for the overwhelming hospitality which was extended to the Society by Colorado. As we comment on the scope of the convention in our editorial pages, this report may enter at once *in medias res*.

The attendance from the East was less than had been hoped for and expected. But while disappointing at the start, this fact did not detract in the least from the success of the meeting. As a matter of fact, it helped to produce quickly that close social intercourse by which in a short time everyone knew everyone and was everyone's friend and brother.

Denver

The total registry list contained 109 names, given in alphabetical order at the end of this report. Out of these there were fifty-two from states outside of Colorado. The Eastern delegation arrived in Denver on two special cars in the early afternoon of *Monday*, Sept. 8, and were received at the railroad station by the local committee enforced by other Denver engineers and business men, and a score of automobiles.

The success of the local committee in making all arrangements was really extraordinary and not enough credit can be given to their work. The committee consisted of the following members: H. C. Parmelee (chairman), W. W. Case, Jr., C. W. Comstock, W. H. Davis, H. C. Eastman, J. B. Ekeley, H. S. Evans, S. Fisher, O. P. Fritchie, F. S. MacGregor, J. L. Malm, G. H. Sethman, C. D. Test, H. J. Wichman and H. J. Wolf.

It was a grand idea to take the party from the station not right to the hotel, but to show them first the beauties of the Queen City of the Plains. After the long railroad journey this crisp automobile ride was wonderfully refreshing. The party went through the big Welcome Arch up Seventeenth Street to the new extensive boulevard and park system, where the greensward produced by constant irrigation was duly admired, back through another residence section of the city, out to Inspiration Point, and finally to the headquarters, the Hotel Shirley, where registration began.

On *Tuesday* morning, the first technical session was held in the Shirley Hotel. A report of all the technical sessions will be found later on.

On Tuesday afternoon visits were paid to the plants of Sutton, Steele & Steele Company, the Western Chemical & Manufacturing Company, and the Henry E. Wood Ore Testing Company.

Smoker

In the evening of Tuesday, an invitation smoker was held in the Pipe and Bowl Room of the University Club. It was the liveliest smoker of the many lively smokers the society has held.

The committee consisted of C. W. Comstock (chairman), H. C. Eastman, F. S. MacGregor, H. C. Parmelee, and F. A. Lidbury, who, as representative of Section Q, was in charge of the proceedings.

A program had been printed, the only weakness of which is that it cannot be reprinted here. There were refreshments and songs, much of the "poetry" having been prepared to idle away what would have been dull moments on the railroad trip in coming to Denver. There was a glorious revival of the Electrochemists' Lovesong: "Sue, dear, turn out the tungstens." There was a wonderful cartoon of the Metallurgical Cow. There were more refreshments and more songs. There were speeches and the home talent of the Denver University Club shone brilliantly. There were limericks. There was a lecture in rhymes, by Dr. Chauvenet, on ferromanurium. There was not one dull second till the climax was reached and the party broke up with the song of "Auld Lang Syne."

Boulder

On *Wednesday* morning special cars were taken to bring the party to Boulder, where the society was shown through the power plant, Professor Ekeley's chemical laboratory, and Professor Evans' electrical laboratory. In the latter the "Elderkin rectifier" was exhibited, which is essentially a commutator driven by a synchronous motor.

The second technical session was held in the University of Colorado. A report of this session will be found below.

After the meeting the society was entertained at luncheon by the university and was cordially addressed by President James F. Baker, of the University. The very enjoyable luncheon was concluded by a hearty vote of thanks to the University and President Baker.

Following the luncheon the members and guests of the society, together with their ladies, were taken by automobiles, provided by the courtesy of the Boulder Motor Club, up beautiful Boulder canyon, where the power plant of the Central Colorado Power Company was inspected. A few of the party extended the trip further up Boulder canyon into the tungsten district at Nederland. It was a truly wonderful "joy ride."

The whole party returned in the evening to Denver.

Golden

On the morning of *Thursday* some visits were made in Denver to the United States Mint, the American Zinc Ore Separating Company, the Globe Smelter of the American Smelting & Refining Company, and the plant of the Screenless Sizer Company.

At 11 a. m. special cars were taken for Golden, where the party were received by professors and officials of the Colorado School of Mines. The society was cordially entertained by the Colorado School of Mines at luncheon in Guggenheim Hall. In an after-luncheon speech the President Emeritus of the School of Mines, Dr. Regis Chauvenet, spoke in poetry of the work of the mining engineer and then expressed the hope that this first Western meeting of the American Electrochemical Society might help to electrify the Rocky Mountains. The hearty thanks of the society were then extended to the School of Mines and Dr. Chauvenet.

After some of the laboratories had been visited, the third technical session followed, a report of which will be found below. After the session the new ore-dressing and metallurgical plant of the Colorado School of Mines was visited. In our issue of May, 1912, pages 269 to 272, we gave a detailed account of the purpose and equipment of the plant; and in a later issue, March, 1913, page 148, we published a statement of the charges for use of any part or all of the plant by private engineers.

Since that time the plant has been brought sufficiently near completion to make the set of interior views of the plant on pages 587 and 589 of additional interest. Some additional equipment is contemplated by the School authorities and will be added as funds become available.

Picnic Dinner

For the evening an informal picnic dinner, tendered by the Colorado Scientific Society, was on the program. The Colorado Scientific Society, of which Mr. G. E. Collins is the president, is the intellectual center of the Rocky Mountain region, and whoever has come in close contact with the big men of that

PHOTOGRAPH TAKEN AFTER FIRST SESSION

region, has heard of the famous yearly dinners of the Colorado Scientific Society at the Denver University Club. They say a man would rather give up Christmas than miss such a dinner.

Now, it was significant that the Colorado Scientific Society undertook to entertain the American Electrochemical Society at dinner on the last day of the Denver-Boulder-Golden meeting; and it was equally significant that a formal full-dress dinner was tabooed and an informal picnic dinner was arranged behind Golden, on top of Lookout Mountain. They say at night Denver presents a wonderful sight from Lookout Mountain—a mass of lights on the plain.

It was to be the crowning success of the entertainment of the American Electrochemical Society by its Denver friends. It was not so to be. The rain came down in torrents. It clearly made the ascent of Lookout Mountain impossible. But it could not spoil in the least the happiness of the party. It could not spoil in the least the picnic dinner, which was immensely enjoyed in Guggenheim Hall. Once more was heard the song of "Auld Lang Syne" and the party went back to Denver.

Colorado Springs and the Pike's Peak Session

On *Friday* morning the party was taken to Colorado Springs, where the members were received at the station by President William F. Slocum, of Colorado College.

Shortly before noon the ascent of Pike's Peak began via the Cog Wheel route from Manitou. The atmosphere was clear after the rain of the night before, though there were clouds enough. But the view from Pike's Peak was glorious through the shifting clouds. When the party arrived by train, they were received by Messrs Bailey, Crosby, and Hinckley, who had walked up to the top the night before. Snow-balling was enjoyed, some light refreshments were taken and innumerable snapshots.

Then the last session of the meeting of the American Electrochemical Society was held on top of Pike's Peak. It is believed that this was the first official session held by any scientific or engineering society at this place or elsewhere at such altitude (the books usually state the altitude as 14,108 ft., but the bench mark of the U. S. Geological Survey in the room where the session was held says 14,083 ft.).

The only business done at this session was the launching of the Colorado Section of the American Electrochemical Society. This was done on motion of Mr. Parmelee, Professor Ekeley, and Professor Wolf, with great enthusiasm, and thus ended officially the Colorado meeting, with the heartiest invitation extended by the East to the West to attend the next spring meeting in New York City.

On the return to Manitou a large number of the party enjoyed an extended ride through the Garden of the Gods.

Cripple Creek

On *Saturday* morning the party went by a special train to the Cripple Creek district. The party was joined by quite a number of the members of the Public Health Association, which had just concluded its meeting in Colorado Springs.

The trip on the Short Line up to Cripple Creek is truly described in the advertisements of the company as a "trip that bankrupts the English language," so we will not try to describe it, but the immense enjoyment of this trip must be recorded.

Before the trip began a large number of the party visited the Golden Cycle Cyanide Mill in Colorado Springs. In the Cripple Creek district the majority of the party visited the Portland Cyanide Mill in Victor, while the remainder enjoyed a trip over the electric lines to Cripple Creek.

In the evening the party broke up. A large majority of the Eastern members left at 11 o'clock via the Santa Fé for Kansas City and Chicago.

Visits to Plants.

Visits were made to a variety of metallurgical plants; and although these were not of an electrometallurgical nature, nevertheless they held considerable interest for the visitors, to many of whom the processes were new and suggestive. It would not be a bit surprising, if, as a result of these visits, some of the apparatus and methods worked out for Western metallurgy should find application in the Eastern chemical industries; especially various apparatus originally devised for the cyanide process, suggested to the visitors new fields of application in various chemical industries.

The first plant visited was the experimental mill of the *Sutton, Steele & Steele Company*, where through the courtesy of Mr. W. S. Myers, the president, special demonstrations were made showing the separation of zinc and iron sulphides by electrostatic means, and the dry concentration of zinc-lead-iron sulphides on pneumatic tables. The grading of grains and seeds also was shown, using the same tables as for ore concentration.

At the *Western Chemical Manufacturing Company*, Mr. L. B. Skinner, superintendent, conducted the party through the plant. This company manufactures commercial and C. P. acids and ammonia, liquid carbonic acid and anhydrous ammonia. One of the features of the plant is the gas-producer power plant, the exhaust from the gas engine being purified and converted into liquid CO_2. The company operates also a 100-ton concentrating mill, treating complex sulphide ores by a process which involves roasting, magnetic separation of the iron constituent, and wet dressing of the lead-zinc residue. Sulphuric acid is made from the roaster gases.

The *Henry E. Wood Ore Testing Company's* mill was of

IN SHIRLEY HOTEL, DENVER

interest on account of the variety of methods available for testing different kinds of ore. In addition to the standard methods of concentration, cyanidation, etc., a method of flotation of sulphide minerals invented by Mr. Wood was demonstrated for the benefit of the visitors. This process has already been described in this journal.[1]

Electrostatic separation by the Huff system was demonstrated at the laboratory of the *American Zinc Ore Separating Company*, by Mr. A. M. Plumb, who also exhibited and operated a new dry jig of his invention. The latter is entirely new in the field of concentration and treats dry ore-pulp by pneumatic jigging. In operation, the machine is comparable to the ordinary hydraulic jig, except that a pulsating current of air is used instead of water.

The *Globe Plant* of the *American Smelting & Refining Company* was visited by some of the members who were particularly interested in seeing a typical western lead smelter. Mr. Frederick Roeser, superintendent, conducted the party through the plant. The principal points of interest were the Huntington-Heberlein and Dwight-Lloyd processes of sinter-roasting, the recovery of blast-furnace dust and fume by the bag-house, and the volatilization and purification of arsenic trioxide from bag-house fume.

The *United States Mint* was also visited and attracted much interest and attention, although the electrolytic refining of gold, in use at this plant, had been temporarily discontinued.

Considerable interest centered in the visit to the *Screenless Sizer Company*, where Mr. B. F. Rice gave demonstrations on the McKesson-Rice screenless sizer. Three types of machines were operated; one each for coal, crushed rock and ore. The screenless sizer is a mechanical device for sizing dry granular material without the use of screens of any sort. Detailed reference has been made to this machine in an earlier issue of this journal.[2]

At Colorado Springs an opportunity was given to visit the cyanide mill of the *Golden Cycle Mining Company*, under the direction of Superintendent A. L. Blomfield. This mill is the largest of Colorado's cyanide plants, having a capacity of 1000 tons of ore per day. It treats only Cripple Creek ore, and is operated not only on company account, but also as a custom mill. The process consists in roasting to oxidize the sulpho-tellurides, after which the coarse gold is recovered by concentration on blankets. The residue is classified into sand and slime, the sand being leached with cyanide solution and the slime thickened, agitated and filtered by vacuum. The resulting gold-bearing solution is precipitated with zinc, and the gold precipitate fluxed and melted.

[1]March, 1912, p. 132.
[2]October, 1911, p. 553.

A different type of cyanide mill was found in the new *Portland Mill* at Victor, in the Cripple Creek district, where Mr. L. W. Lennox, assistant superintendent, conducted the party and explained the steps in the process. Here only low-grade mine and dump ore is treated, having a gross value of not more than $3.25 per ton. The ore is ground in cyanide solution in Chilean mills, and concentrated on Wilfley tables to remove the sulpho-tellurides which are shipped to the smelter. The remaining pulp is classified into sand and slime, the former being discarded and used for stope filling in the mine. The slime is thickened and agitated, and finally filtered on a rotary type of continuous vacuum filter. The gold solution is precipitated by zinc dust and collected in filter presses, from which it is removed from time to time, fluxed and melted.

Entertainments

In addition to the social functions mentioned above several dinners and luncheons were given for visiting members by local engineers. Mr. G. E. Collins was host at a lunch at the Denver Club. Mr. C. W. Comstock tendered a dinner at the University Club. Mr. J. V. N. Dorr entertained a party at dinner at the Antlers, Colorado Springs. Mr. J. P. Evans, Mr. H. C. Parmelee, and Mr. L. Searing entertained other parties in Denver.

Ladies' Entertainment

The entertainment of visiting ladies was in the hands of a local committee consisting of Mesdames G. E. Collins, L. B. Skinner, J. V. N. Dorr, and H. C. Parmelee, of Denver, Mrs. J. B. Ekeley, of Boulder, and Mrs. C. D. Test, of Golden.

On the first day of the meeting a well-appointed luncheon was served at noon in the "blue room" on the fourteenth floor of Daniels & Fisher's tower, in Denver. In the evening Mrs. Collins entertained at dinner, following which there was a theater party.

At Boulder an automobile ride was arranged, giving a wonderful view of mountains, foothills and plains.

During the afternoon session at Golden, a reception and musicale was held at the home of Mrs. Test.

All of these functions were delightful, and were thoroughly enjoyed by the ladies who were fortunate enough to attend the meeting.

In the following we give a complete report of the papers presented at the technical sessions, together with discussions.

Technical Session at Denver

The first technical session was held in the Shirley Hotel, Denver, on Tuesday, September 9.

The meeting was called to order at 10 A. M. by the president of the Society, Dr. E. F. Roeber, who expressed the sincere thanks of the Society for Colorado's wonderful hospi-

tality. Mr. H. C. Parmelee, the Chairman of the Denver local committee, followed with a number of announcements on the arrangements made for the afternoon and the following days.

The secretary of the Society, Professor Joseph W. Richards, read a telegram of good wishes from the National Electroplaters' Association.

The following four papers were then read and discussed: Some Aspects of Heat Flow, by E. F. Northrup; Flow of Heat Through Furnace Walls and the Shape Factor, by Irving Langmuir; the Heat Resistivity of Graphite and Carbon, by J. W. Richards; the Electrolysis of Cyanide Solutions, by E. F. Kern. In the absence of the authors the papers of Dr. Northrup and Dr. Langmuir were presented by Mr. Hansen, the paper of Dr. Kern by Professor Schoch.

Some Aspects of Heat Flow

The elaborate paper by Dr. **E. F. Northrup,** of Princeton University, on "Some Aspects of Heat Flow," emphasizes in the introduction the advantages of viewing a problem in its various phases through the true analogies which it bears with similar problems. After a discussion of the general equations expressing analogies, the author takes up specifically heat flow analogies and gives a long table of the physical analogies and dissimilarities between flow of heat and flow of electricity.

The author then discusses why measurements of thermal conductivity are difficult. The first difficulty is that in producing a flow of heat with which to make the measurement, by creating a temperature difference, we vary more or less the quantity we desire to measure.

The second difficulty is the extreme slowness with which

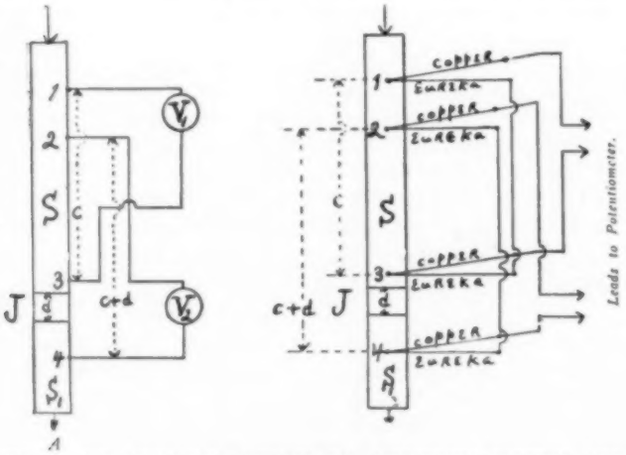


FIG. 1.—AN ANALOGOUS METHOD FOR MEASURING ELECTRIC AND THERMAL CONDUCTIVITIES

temperature equilibrium is re-established after once being disturbed. The third and perhaps the greatest difficulty results from the impossibility of giving to any path of heat flow a thermal insulation which even approximates perfection. This difficulty increases as the thermal conductivity of the material being measured decreases.

A fourth and less understood difficulty which if not surmounted will introduce very great errors into the measurements, is the very large surface film resistance which is always found at the surfaces of thermal conductors.

In the light of the analogies between heat and electrical phenomena, given in the first part of the paper, the author discusses in the second part how the above difficulties may be in part overcome, by using methods of measurement analogous with the fundamental electrical methods for measuring electrical resistance.

The four fundamental methods of measuring electrical resistance are:

(*a*) By measuring the fall of potential and the current which flows,

(*b*) By comparing the fall of potential over a standard resistance and the specimen,

(*c*) By the balance method of the Wheatstone bridge, and

(*d*) By the balance method of the Kelvin Double Bridge.

In adapting any of these methods to the measurement of thermal resistance, a thermocouple is substituted for the voltmeter or potentiometer. But there is no single thermal device, as a substitute for the ammeter. When it is required to measure heat flow, it is, therefore, necessary to determine the change per unit of time produced by the heat in some material substance. The quantity of water raised one degree or the quantity of ice melted in the unit of time are methods commonly employed to determine the rate at which the heat flows or is delivered. Of course, the rate at which heat is produced by the source of heat can be very precisely measured and if the heat which flows through to the opposite side of the specimen is also measured the quantity of heat which does not pass between the temperature points can be determined.

Method (a). The analogous of the electrical method (*a*) stated above is to determine the mean thermal resistance by measuring the three quantities. The temperature difference, the heat which flows in the unit of time, and the elapsed time.

As this is the least precise of the electrical methods it is even less so in the thermal case. The time and the temperature difference can be measured with high precision by the quantity of heat which flows through a selected path cannot. The difficulty is largely, of not chiefly, due to the impossibility of knowing the paths in which all the heat flows.

Method (b). An analogue of the electrical method (*b*), applied to determinations of thermal resistivities, has been carefully tested by the author in its application to measuring the thermal resistance between two plane surfaces which press together.

Referring to *A*, Fig. 1, let a rod of homogeneous material and uniform cross-section be joined end on with another rod of like material and cross-section. At the surface of union *J* let there be either a contact resistance or another short rod of different material and of length *d*.

Let 1, 2, 3, 4, be potential points so located that the length *C* of the material *S* included between points 1 and 3 is exactly equal to the length of the material *S* included between points 2 and 4. Let d_1 be the deflection of the instrument V_1 and d_2 the deflection of the instrument V_2. Both instruments must have the same constant but they need not necessarily read in volts.

Then $d_1 \propto C$ and $d_2 \propto C + x$ which gives by division

$$x = \frac{d_2 - d_1}{d_1} C$$

This equation gives the resistance of the length *d* of the material at *J* in terms of a length *x* of the material *S*. If *c* is taken in centimeters *x* is in centimeters. If the length *d* of the material *J* is made zero as nearly as possible then *x* is the contact resistance of the point at *J* in equivalent lengths of the material *S*. This method will be recognized as the one employed by F. A. J. FitzGerald and A. T. Hinckley[8] for measuring the resistance of electrode joints.

Refer now to *B*, Fig 1, and we have the exact analogy for the thermal case. The gap at *J* may be filled with a film of air or liquid, or the gap may be closed by pressing the piece *S* tightly against the piece S_1. In the former case *x* gives the thermal resistance in terms of equivalent length of *S* of a film of liquid of thickness *d*, and in the latter case the thermal resistance of a joint between *S* and S_1 for the particular pressure employed.

In the apparatus constructed *S* and S_1 are round rods 3.8 cm. in diameter, of electrolytic copper. The ends at *J* are very true surfaces. The separation at *J* can be measured by a micrometer, and the length *C* is made very accurately 10 cm. The rods are carefully heat-insulated with baked lavite. The lower end is kept at zero degrees in ice water, and the upper end is heated electrically.

It may be mentioned here, however, that the thermal contact

[8]Trans. Am. Electrochem. Soc., 23, 333 (1913). Met. & Chem. Eng'ing, May, 1913, vol. 11, p. 279.

resistance of the two plane copper faces when pressed together with a moderate pressure is equal to 31.2 cm. of length of copper. It will be noted that the precision of the method is unaffected by any leakage of heat between the points 2 and 3, and only the *difference* in the leakage between the points 3 and 4 and the points 1 and 2 can affect the measurement. As the distances 1 = 2 and 3 = 4 are very small, the former being only 0.6 cm., and as the lavite insulation is very good, errors from this heat leakage are thought to be very small.

The method of measuring thermal resistances by comparing

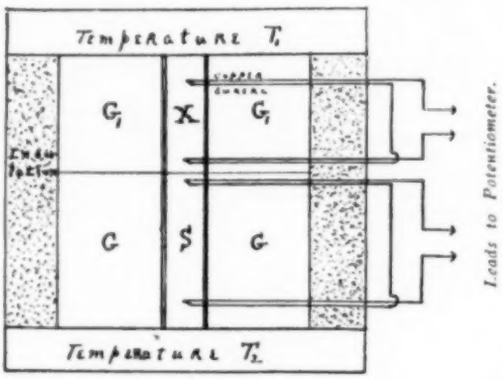


FIG. 2.—METHOD OF MEASURING THERMAL CONDUCTIVITIES

the fall of temperature over a standard material and the material to be measured should prove a very precise one if properly carried out. The diagram, Fig. 2, suggests in outline the way the author would propose to execute the method for either metallic materials or so-called heat insulators.

The standard material S should be copper for the metals and a substance like alundum of a standard grade and composition for high thermal resistance materials. G, G is a guard cylinder of the same material as the standard, and G_1, G_1 a guard cylinder of the same material as the sample X.

The results obtained should give the ratio $X/S = E_1/E_2$ with excellent precision. The proposed method is exactly analogous to the electrical method (*b*).

Method (c). No exact analogy to the electrical method (*c*) occurred to the author as having much value in thermal measurements, but the method of the Wheatstone bridge suggested a method for obtaining the relative thermal conductances of similar coils of wire when not impregnated and when impregnated with different insulating compounds.

This method was tested under the supervision of the author by Mr. William Eves, 3rd, and described, together with the results obtained, in an article by Mr. Eves in the September, 1913, issue of this journal, page 503.

Method (d). Concerning the thermal analogue to electrical method (*d*) Dr. Northrup speaks as follows:

"The thermal analogue of the Kelvin double bridge method (*d*) of measuring low resistances and of obtaining the conductivity of low resistance, large temperature coefficient wires in terms of a standard of conductivity (Hoopes' Bridge Method) has not been tried out by me. I have, however, tested experimentally the principle of the method and I believe it is capable of being developed into a very useful method. The diagrams *A* and *B* of Fig. 3 below are self explanatory.

"In either of the diagrams (*A*) or (*B*), the galvanometer shows no deflection and the bridge is balanced when $S/X = a/b$, provided the ratios a/b and α/β are maintained the same. The connection in B shown in dotted line may or may not be made.

"In the thermal case, thermocouples are the sources of current which operate the galvanometer. The method is a zero method in every respect and it is not necessary to know the quantity of electricity or the quantity of heat which flows. By maintaining the cold end as much below as the hot end is above the surrounding temperature it is evident that heat losses from the sides of the thermal path would not introduce much error. Side guards through which the temperature gradient is made the same as that through the standard and the sample would effectually reduce this source of error."

In conclusion, Dr. Northrup expresses the following opinions on the use of standards of thermal conductivity:

"It will be at once recognized and perhaps objected to, that the above methods, taken as the analogues of the electrical methods for measuring resistance, give only *comparative* results.

"But why not adopt standards of thermal resistance, and standards of thermal conductivity the same as in electrical measurements we adopt standards of electrical resistance and a standard (Matthiessen's Standard) of electrical conductivity? It seems to me that great advantages would result from this procedure. Some of these advantages are apparent from the suggestions regarding measurements given above. Others are:

"The corrections for losses of heat through the insulation of the path of the heat flow, could be made negligibly small.

"The principles of the Kelvin bridge, which avoids all contact resistances (surface film resistances in the thermal case) could be applied.

"The measurements could all be made by accurately measuring only temperature-differences, the absolute temperature being only roughly required.

"The measurements could be carried out at absolute temperatures chosen through a wide range.

"The measurement of a quantity of heat is never required.

"To be sure, all results would be given in terms of a ratio of thermal resistance to the thermal resistance of the selected standard. But when by long and carefully conducted investigation the specific thermal resistance of the material selected for

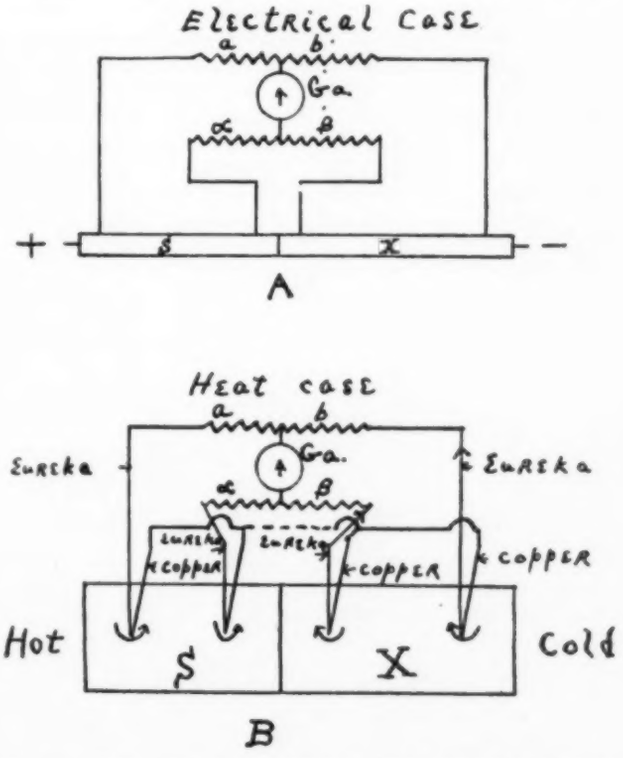


FIG. 3.—APPLICATION OF THE KELVIN DOUBLE BRIDGE METHOD TO THE DETERMINATION OF THERMAL CONDUCTIVITIES

the standard is obtained, all comparisons made with this standard can be expressed in the usual thermal units.

"I would suggest that two standards be adopted—one for low thermal conductivity materials and one for high conductivity materials. The first might consist for example of a standard grade of alundum cement packed under a given pressure and baked to a maximum given temperature. The second might consist of 100 per cent electrical conductivity copper. The thermal conductivity of this last is already pretty

well known, and one careful investigation would determine the other.

"I offer this sugestion in the hope it may meet with favor and prove to be as good in practice as it seems to be in theory.

"Interest in the properties of matter at temperatures above those at which organic life can exist, but at which very many industrial processes are carried on, is constantly increasing. I venture to say that no method in learning how to investigate those properties will prove more fruitful of results than the method whereby phenomena are viewed in the light of their natural physical connections and the analogies which join them together in groups and classes."

Dr. Northrup's paper was briefly discussed by Dr. J. W. Richards and Mr. C. W. Comstock with reference to a few details in the author's table of comparison between electricity and heat flow.

Flow of Heat Through Furnace Walls—The Shape Factor

The paper on this subject by **Irving Langmuir, E. Q. Adams** and **G. S. Meikle,** of the Research Laboratory of the General Electric Company, Schenectady, is an important continuation of Dr. Langmuir's paper presented at the Atlantic City convention of the Society (this journal, May, 1913, p. 278). The ordinary formula for the flow of heat through plates or rods of solid materials may be written:

$$W = A/t\, k\, (T - T_0)$$

where W = the heat flow, expressed in watts,
A = area of plate or cross-section of the rod,
t = thickness of the plate or length of the rod,
$T - T_0$ = the difference of temperature between the two sides of the plate or between the ends of the rod,
k = heat conductivity of the material of the plate or rod in watts per cm. per degree.

In most practical cases of heat flow the problem is more complicated than this. Usually the heat is not flowing between parallel surfaces, or at least the areas of the two bounding surfaces are different. The above equation, as it stands, applies only between parallel surfaces through a body of uniform cross-section. For bodies of other shapes, A will vary along the path of heat flow. However, if the area of inflow and outflow are fixed, the ratio A/t will have a definite value, depending only on the shape of the body. This quantity we shall call the shape factor, and will represent it by S. Our formula thus becomes:

$$W = Sk\, (T - T_0)$$

In case the heat conductivity is a function of the temperature, the equation should be written:

$$W = S \int_{T_0}^{T} k\, dT$$

S, shape factor, is a quantity of the dimension of a length which depends only on the shape and size of the body and the position of the surfaces by which the heat enters and leaves the body.

It is with the determination of this shape factor that the present paper deals. The first part of the paper discusses in detail the theoretical determination of the shape factor, the second part describes an experimental determination, based on the analogy between flow of heat and flow of electricity. The chief results are summed up as follows:

Only in three simple cases, planes, cylinders and spheres, can S be determined rigorously by calculation. In other cases certain simplifying assumptions must be made, so that the results are of limited accuracy.

There are three types of assumptions that are useful in calculating the shape factor:

A. Assuming some given shape for the isothermal surfaces. This is equivalent to placing in the body perfectly conducting but infinitely thin surfaces. The shape factor calculated in this way is, of course, too high, and must be considered an upper limit. Many different assumptions may be made regarding the shape of the isothermal surfaces, and since the results will always be too high, that assumption is the best which gives the lowest result.

B. Assuming some given shape for the heat flow lines. This is equivalent to compelling the heat to flow in a given way by interposing infinitely thin surfaces of perfect heat insulating material. The shape factors calculated this way will be too low, and the best assumption is that which gives the highest value.

By applying both methods *A* and *B*, we can usually show that the shape factor must lie between quite narrow limits.

C. Very good approximate results may often be obtained by imagining parts of the surfaces of inflow and outflow of heat to be replaced by spheres or cylinders of equal area.

Experimentally the shape factor may be very conveniently determined for bodies of any shape by constructing small models of copper and glass and determining the electrical resistance of a saturated copper sulphate solution placed in them.

The values of the shape factors of heat insulation placed on bodies of various shapes have been determined both theoretically and experimentally. The results are given in the following formulas:

Parallel Planes: $S = A/t$ where A is the area of the planes and t the distance between them. This applies rigorously when the planes are infinite in extent.

Concentric Cylinders:

$$S = \frac{2\pi l}{\log_e \frac{b}{a}} = \frac{2.73\, l}{\log \frac{b}{a}}$$

where l is the length of the cylinders, b the diameter of the outer cylinder and a the diameter of the inner one. This formula is rigorous for infinitely long cylinders.

Concentric Spheres:

$$S = \frac{2\pi}{\frac{1}{a} - \frac{1}{b}} = \frac{\pi ab}{t} = \frac{\sqrt{AB}}{t}$$

where b is the diameter of the outer, a the diameter of the inner sphere, B the surface of the outer and A the surface of the inner sphere, t the thickness of the insulation, i. e., $\frac{1}{2}(b - a)$. This formula is rigorous.

Square Edge: The shape factor is calculated for the *inner* surface up to the edge by the formula $S = A/t$, where A is the surface *inside* the insulation and t the thickness of the insulation. To this is added $0.54\ \Sigma l$, where Σl is the sum of the lengths of all the square edges. The result is the shape factor for the whole insulation. The above factor 0.54 was experimentally determined. The theory gave 0.477 as a lower limit.

Square Corner: To the shape factor of the plane faces (inside the insulation) and the square edges add that of the square corners, which is equal to $0.15\ n\ t$. Here n is the number of corners and t is the thickness of the insulation.

Plane Edge: Where two square edges are so close together that their distance apart is less than one-fifth of t, the thickness of the insulation, then the shape factor is found by adding to the shape factor of the faces that of the "plane edge," which is equal to $0.93\ \Sigma l$. Here Σl is the total length of the plane edges. This factor 0.93 was determined experimentally. The calculated value was 0.95.

Plane Corner: To the shape factor of the plane faces (inside the insulation) and plane edges add that of the plane corners, which is $0.087\ n\ t$. Here n is the number of such corners and t is the thickness of the insulation. The factor 0.87 was experimentally determined. Calculation gave 0.15.

Small Square Rod: Where all the dimensions except the length are less than one-fifth the thickness of the insulation, then the shape factor is obtained from the formula:

$$S = \frac{6.4\, l}{\log_e \frac{b}{a}} = \frac{2.78\, l}{\log \frac{b}{a}}$$

where b/a gives the ratio of the surfaces of the outer and inner prism. The coefficient 2.78 was experimentally determined. Calculation shows that the coefficient must lie between 2.73 and 3.47.

Small Cube: Where *all* the dimensions of a rectangular

parallelopiped are less than one-fifth of the thickness of the insulation, the shape factor should be calculated from:

$$S = 0.79 \frac{\sqrt{AB}}{t}$$

where A and B are the surfaces of the inner and outer boundaries of the insulation and t is the thickness of the insulation. The coefficient 0.79 was found by experiment. Calculation gives 0.724.

Rectangular Parallelopipeds Covered with Uniform Thickness of Insulation: The following formulas apply to all those cases where the furnace is of rectangular shape with uniform wall thickness:

1st Case. All three dimensions are greater than 1/5 t. For this case the shape factor can be calculated simply:

$$S = A/t + 0.54 \Sigma l + 1.2 t$$

2nd Case. Two dimensions greater than 1/5 t and one dimension less than 1/5 t. We then have:

$$S = A/t + 0.465 \Sigma l + 0.35 t$$

3rd Case. One dimension greater than 1/5 t and two dimensions less than 1/5 t. We have:

$$S = \frac{2.78 l}{\log \frac{b}{a}}$$

as explained under the heading "Small Square Prism."

4th Case. All three dimensions less than 1/5 t:

$$S = 0.79 \frac{\sqrt{AB}}{t}$$

as explained under the heading "Small Cube."

General Formula for the Cube. For the cube a single formula can be made to cover all four of the above cases:

$$S = \frac{6 a^2}{t} + 6.5 a + \frac{1.2 t}{\sqrt{1 + 016 \frac{t^3}{a^3}}}$$

where a is the length of the side of the cube and t is the thickness of the insulation covering it.

Any actual problem may usually be solved by considering the insulation made up of various parts for each of which the shape factor is given in the table. An actual problem will illustrate.

Given a rectangular electrically heated oven, with inside dimensions 8 x 10 x 20 in. The walls are of a uniform thickness of 8 in. This makes the outside dimensions 24 x 26 x 36. The shape factor is calculated from the formula:

$$S = A/t + 0.54 \Sigma l + 0.15 n t$$

Here A is the area of the inside of the wall of the oven. This is 880 sq. in., thus:

$$\begin{aligned} 2 \times 8 \times 10 &= 160 \\ + 2 \times 10 \times 20 &= 400 \\ + 2 \times 20 \times 8 &= 320 \end{aligned}$$

The thickness of insulation is 8 in. Hence, $A/t = 110$. The sum of the lengths of the edges Σl is 152 in., thus:

$$\begin{aligned} 4 \times 8 &= 32 \\ + 4 \times 10 &= 40 \\ + 4 \times 20 &= 80 \\ \hline 152 \times 0.54 &= 82 \end{aligned}$$

The third term 0.15 $n t$ is 9.6, whence the shape factor is the sum of the three terms:

$$\begin{aligned} &110 \\ &82 \\ &9.6 \\ \hline &201.6 \end{aligned}$$

It is interesting to compare this result with that obtained by the usual methods.

The most common method is to calculate the shape factor from the formula $S = A/t$, where A is the arithmetical mean of the inner and outer surfaces of the oven. The outer surface is 4848 sq. in. This would give for the shape factor:

$$S = \frac{808 + 4848}{2 \times 8} = 353.5$$

This is very different from the 201.6 obtained by our new method, and well illustrates the serious error that may be made by using the ordinary rough method.

If the geometric mean be employed instead of the arithmetic, the result is:

$$S = \frac{\sqrt{808 \times 4848}}{8} = 247.4$$

This is much better than 353, but is still quite different from 201.6, being 23 per cent too high.

The paper was discused at some length by Messrs. C. W. Comstock, C. A. Hensen, F. A. Lidbury and J. W. Richards. A communicated discussion by Dr. E. F. Northrup was read in which a high compliment was paid to the scholarly treatment of the subject by the authors in developing their "sound theory which henceforth must form the starting point in any practical calculation or scientific tests in the difficult subject of heat flow." Dr. Northrup points out, however, that in the calculation of the heat flow from actual furnaces there are other factors, such as surface resistances, variable and uncertain conductivities, departures from the state of temperature equilibrium, heat losses by the outflow of hot gases, etc., which have such large relative importance that it is immaterial that the shape factor be known to a close precision. Dr. Northrup also gave some formulas which are useful when it is required to determine the temperature of any point in the insulation, the temperature of two other points being known. They relate to the cases of parallel planes, concentric spheres and concentric cylinders.

Heat Resistivity of Graphite and Carbon

A paper by Professor **Jos. W. Richards,** of Lehigh University, on the heat resistivity of carbon and graphite, gave the results of an experimental investigation carried out in the following way: Two blocks each 20 x 20 x 10 cm. (8 x 8 x 4 in.) were placed on each other so as to form a cube 20 cm. (8 in.) on the side. In the center a cubical cavity was made 2.5 cm. (1 in.) on the side. Two passages 1 cm (0.4 in.) in diameter were then made from the outside to the inner cavity, and a smaller hole 5 mm. (0.2 in.) in diameter was drilled from the middle of an outside face to within 1 mm (0.4 in.) of the inner cavity. The larger passages were for the introduction of electric-light carbons, passing through glass tubes which fitted tightly into the passages; the small hole was for a thermo-couple (iron-nichrome) for measuring the temperatures when thermal equilibrium was reached. Currents up to 1000 watts were used in the arc.

From several careful determinations the following figures for thermal resistivity (in thermal ohms, i. e., degrees per watt) of these two materials were obtained:

National Carbon Company carbon (202°-853°)=36.8 thermal ohms for a cm. cube.

Acheson graphite (240°-420°) = 3.69 thermal ohms for a cm. cube.

Ratio = 10:1.

From a discussion of the possible errors it is concluded that the ratio in question is at least 10 to 1, but possibly higher, though the ratio is believed to be accurate within 10 per cent.

In the conclusion of the paper a comparison is given with the results of other investigators.

Dr. Richard's paper was discussed at some length by Messrs. C. G. Fink, C. A. Hansen, F. A. Lidbury, J. W. Richards and E. F. Roeber. Dr. Carl Hering, in a long communicated discussion, questioned the accuracy of the experimental method in various respects and protested against the comparison of the author's results with his own determination of "thermal conductivities" under electrode conditions, which are really in different quantity.

Electrolysis of Cyanide Solution

The paper on this subject by Dr. **Edward F. Kern,** of Columbia University, gives the results of an investigation undertaken with the idea of determining the validity of some of the conflicting statements which were found in reviewing the

extended literature on the electrolysis of cyanide solutions.

A review of the literature on the subject is first given and the published information is summed up as follows:

Electrolysis has, under favorable conditions, been utilized as a means of precipitating and recovering gold and silver from cyanide leach solutions by electrolyzing the solution with suitable electrodes and with current density of 0.01 to 0.6 amp per sq. ft. (0.11 to 6.5 amp per sq. m). The metal was deposited as a dense film when the current density was properly regulated with regard to the composition, the concentration and the circulation of the solution. The deposit formed is pulverulent and non-adherent if the solution is dilute, the circulation sluggish, and the current density high.

Iron anodes dissolve in cyanide electrolytes causing consumption of cyanide and contamination of the solution by precipitates of iron compounds.

Carbon and graphite anodes are satisfactory in cyanide electrolytes when used at low current density, but they disintegrate at high current density, causing "fouling" of the solution.

Peroxidized lead anodes are not dissolved during electrolysis of cyanide solutions, and the consumption of cyanide by their use is less than when metallic iron anodes are employed.

Fused iron oxide anodes are permanent in cyanide electrolytes, and the cyanide consumption by their use is small.

Oxygen, supplied to cyanide leach solutions either by additions of chemicals or by electrolysis, is beneficial for the treatment of certain refractory ores, in that the extraction is thereby accomplished more rapidly and more efficiently. Electrolysis is claimed to be a cheaper and more efficient method of supplying oxygen to cyanide leach solutions than by the addition of chemical oxidizers.

Regeneration of cyanide "work" solutions, which contain cyanogen compounds, is possible by electrolysis. There is controversy as to whether alternating current can be used for this purpose.

Electrolysis of solutions containing sulphocyanide and cyanamide by means of direct current at high current density (50 amperes per square foot, 540 amperes per square meter) produced solutions of cyanide. Fused iron oxide anodes were found to be the most satisfactory for this purpose.

Electrolysis of solutions containing only cyanide produces cyanates, which will not dissolve gold and silver.

Telluride gold ores were effectively treated by use of solutions which contained an halogen-cyanide compound, which was generated by electrolysis of solutions containing an halide salt and cyanogen compounds, employing direct current at high current density for producing the active halogen-cyanide compound.

An account of the experimental investigation carried out at Columbia University is given in the second part of the paper under the following three headings: permanence of anodes in cyanide electrolytes; electrolysis of cyanide solutions with insoluble anodes; electrolysis of cyanide solutions containing sulphocyanide and ferrocyanide. The results are summed up as follows:

The electrolysis of cyanide solutions by direct current and by means of insoluble anodes is accompanied by progressive consumption of cyanide, which is the result of oxidation of the cyanide to oxy-cyanide compounds.

Anodes of metallic iron, nickel, and lead are dissolved during the electrolysis of cyanide solutions; these metals on entering the solution are immediately precipitated, the lead as hydroxide, and the iron and nickel as a mixture of hydroxide and cyanogen compounds. The consumption of cyanide by means of these anodes was relatively greater the lower the current density, as at high current density oxygen was simultaneously liberated, and consequently less metal was dissolved. The consumption of cyanide was less in the case of the lead anodes than with either the iron or the nickel.

Peroxidized lead and "passive" iron anodes were found to be more permanent than metallic anodes of either iron, nickel or lead. There was no apparent corrosion of either the peroxidized lead or the "passive" iron anodes so long as they kept continuously in use, but exposure to the atmosphere for several days destroyed their permanency, due to spontaneous oxidation. The "passive" iron anodes were found to be more satisfactory than peroxidized lead anodes for electrolyzing cyanide solutions in that the cyanide consumption was much less and the voltage was slightly less in most cases.

Electrolysis of cyanide solutions, which were used for leaching a special refractory gold and silver ore containing sulphide minerals, was found not to be beneficial either in reducing the cyanide consumption or increasing the percentage extraction.

Low current density at both the anode and the cathode gave less consumption of cyanide, and in several cases seemed to have produced a slight amount of "active" solvents, but not enough to compensate for the loss of cyanide which resulted by the electrolysis.

The cyanide consumption during electrolysis of cyanide solutions was greater when the current density at the cathode was run higher than at the anode, which suggested that the loss of cyanide is the result of oxidation, with the formation of oxy-cyanogen compounds. The lower the current density at the anode and the higher it is at the cathode, relatively greater is the cyanide consumption.

When cyanide solutions containing sulphocyanides or ferrocyanides are electrolyzed, the cyanide consumption was much less than that which occurred in pure cyanide solutions, which indicates that sulphocyanide and ferrocyanide act as protective agents during the electrolysis of cyanide solutions.

The increased alkalinity of cyanide solutions reduced the cyanide consumption during electrolysis, due to increasing the conductivity of the solution. The higher the voltage the greater the cyanide consumption, and *vice versa*.

The electrolysis of cyanide leach solutions had no apparent effect upon reducing the time required for treating a refractory ore nor in increasing the percentage extraction.

Peroxidized lead anodes and "passive" iron anodes are corroded in cyanide electrolytes which contain sulphocyanide, if the electrolysis is conducted at high current density. No apparent corrosion occurred when a low current density (below 3 amp. per sq. ft., or 32 amp. per sq. m.) was used.

"Passive" iron anodes are more satisfactory than peroxidized lead anodes for the electrolysis of cyanide solutions which contain either sulphocyanides or ferrocyanides in that by their use the cyanide consumption is very much less and the voltage slightly less. The lower the current density the smaller the consumption.

The regeneration of cyanide solutions which contain sulphocyanide and ferrocyanide does not occur by electrolysis with direct current, whether the conditions of electrolysis be made oxidizing or reducing by varying the relative current densities at the anode and the cathode.

Dr. Kern's paper elicited considerable discussion, in which Messrs. G. H. Clevenger, F. C. Frary, F. A. Lidbury, J. W. Richards, and E. P. Schoch participated.

Professor Schoch thought well of the fundamental idea of the Clancy patents.

Professor Clevenger gave an interesting account of his experience in a Butters cyanide mill. They had tried there anything in the way of "insoluble" anodes, but passive iron. They found that peroxidized lead anodes had a life of about a year. He thought that the use of passive iron was an interesting and good suggestion. In the whole Professor Clevenger agreed with the conclusions of Dr. Kern's paper, though he thought they were based in part on insufficient evidence.

Dr. Richards described a mercury cathode cell of the Castner type with which he had made some laboratory experiments. It is a double-compartment cell, the two compartments being separated from each other by a baffle in the center of the cell. This baffle dips into the layer of mercury provided on the bottom of both compartments. The anode compartment contains a solution of caustic soda, sodium being deposited onto the mercury and the sodium amalgam being transferred to the other (the cathode) compartment. The latter contains gold sodium cyanide solution. Gold is deposited

and the cyanide solution is regenerated from the amalgam.

Mr. Lidbury remarked there would be an accumulation of caustic, but this would be an asset. Mr. Clevenger spoke of a similar scheme which was to be tried on a large scale, but as far as he knew nothing had come of it. He thought the scheme was not impossible.

Session in Boulder

The second technical session, held on Wednesday morning in the University of Colorado, in Boulder, was taken up by the reading and discussion of two papers. The paper by Clevenger and Hall on electrolysis of cyanide solutions was presented by Professor Clevenger; the paper by Lyon and Keeney on possible applications of the electric furnace to Western metallurgy was presented by Mr. Lyon. Both papers elicited a very animated and extended discussion, lasting in each case for almost an hour. As matter of fact, the discussion would have been continued further, if the announcement had not to be made that in spite of the heated discussion the lunch was getting cold.

Electrolysis of Aqueous Solutions of the Simple Alkaline Cyanides

The paper on this subject by Professor **G. Howell Clevenger,** of Leland Stanford University, and Mr. **Mortimer L. Hall,** of La Touche, Alaska, gives the results of an experimental investigation in which chemically pure potassium cyanide was used throughout. For details of the various series of experiments the reader must be referred to the full paper which also contains interesting notes on methods of analysis for the electrolyzed solution and a summary of the reactions (in part hypothetical) occurring during and after electrolysis.

The authors' conclusions are as follows:

The bulk of the decomposition of cyanide occurring during electrolysis is due to oxygen liberated at the anode through the decomposition of water.

The principal final reaction in solutions of cyanide containing protective alkalinity, which in cyanide mill practice is usually due to lime, is the formation of the corresponding alkali carbonate. This accounts for the formation of large amounts of calcium carbonate during the electrolytic precipitation of gold and silver from cyanide solutions.

A consideration of the reaction previously discussed will explain the failure in many cases to obtain regeneration of cyanide when such regeneration is theoretically possible. It is apparent that the decomposition of cyanide may easily be equal to or greater than that regenerated through the precipitation of the metal in solution.

The Liebig titration for the estimation of cyanide in an electrolyzed solution gives results which are low.

The changes taking place in fresh and electrolyzed cyanide solutions, upon standing, are different.

While not wishing to discourage investigators working along the lines of aiding extraction with refractory ores by electrolysis, we think that it is of importance to call attention to the disadvantages which may arise through the indiscriminate use of electrolysis with an ore pulp. First, a large loss of cyanide may result from which there is no benefit derived, and, second, electrolysis may actually interfere with extraction through the formation of a coating of calcium carbonate upon the ore particles.

The discussion was opened by Mr. Lidbury who in commenting on Professor Clevenger's paper and on Professor Kern's paper of the day before, thought that not enough attention was paid to a fundamentally important principle, often emphasized by Professor Bancroft, namely, that all electrolytic processes should be considered first of all as chemical reactions. We should endeavor to disclose the pure chemistry of the reaction. What is electrolysis called upon to do? What are the chemical conditions and the chemical reactions which we desire to produce? What are the anode reaction and the cathode reaction, if strictly separated and investigated separately? The investigation should be conducted with exact observance of conditions, such as steady temperature, steady potential drop, etc. The evolved gases should be investigated, etc.

Professor Clevenger replied that his investigation had been purposely carried out just in the same way as the work under discussion had been done by the various practical experimenters all over the country. Temperature cannot be maintained constant in commercial mill practice. But he agreed that Mr. Lidbury was right about the way that future investigations must be carried out.

Professor Richards said that practical cyanide men were well acquainted with many of the chief chemical problems of their work, like the action of different solvents, etc. One chief difficulty of the application of electrolysis to cyanide solutions was found in the fact that for the electrolytic deposition of the gold only 2 per cent of the current was usefully employed, and 98 per cent was wasted and great care had to be taken to make this 98 per cent of current harmless so as not to destroy the cyanide. As to the life of lead peroxide anodes in cyanide solutions he said that if lead anodes were first coated with peroxide in an alkaline solution they would be found far more resistant than if oxidized in an acid solution.

Professor Frary questioned some of the hypothetical reactions in the paper.

Professor Schoch emphasized the wonderful opportunities in bringing in a meeting like this the practical and the so-called theoretical men together. As to the necessity of separating the anodic from the cathodic reaction, this was most important in the first teaching of electrolysis, though many widely used text books were shocking in overlooking this fact. Mr. Lidbury's criticism should make professors using such text books blush.

Mr. Skirrow thought that in a careful investigation conditions of temperature, current density, etc., should be varied one at a time. It was clearly impossible to study everything at once.

Possible Applications of the Electric Furnace to Western Metallurgy

The paper on this subject, by **Dorsey A. Lyon** and **Robert M. Keeney,** of the U. S. Bureau of Mines, first gives a review of the present status of the electric furnace in *smelting iron ores.* The fact that coke is unsatisfactory as a reducing agent in the electric iron ore reduction furnace (chiefly on account of the much better electric conductivity of coke as compared with charcoal) seems to limit the electric iron reduction furnace to the use of charcoal. Hence it is necessary that such a furnace be located in close proximity to a well timbered region, where charcoal as well as electric power can be produced at a low cost. This is unfortunate, especially as regards the situation in southern California and in other of our western States, where there are quite large iron deposits of A-No. 1 ore, but where coke is too expensive to permit of ordinary blast furnace smelting, and where the use of charcoal for electric furnace work is entirely out of the question, as there are no forests to furnish the wood necessary for its production. On the other hand, crude oil is generally more or less plentiful and comparatively cheap in such districts, especially in California.

As a result of a preliminary investigation conducted by the metallurgical section of the U. S. Bureau of Mines on the possibility of using crude oil as a reducing agent, it seems as if about the only manner in which crude oil may be used for this purpose is to first convert it into a fixed gas and then introduce this into the crucible of an electric furnace, thus preheating the gas to such a temperature that it will effectively reduce the iron oxides as it passes up through the shaft of the furnace.

A review is given of the commercial development of electric iron smelting in Scandinavia and California. From the Scandinavian reports it is shown how step by step the results have been improved. The output has been increased from 3.10

to 3.20 tons of iron per h. p. year. The electrode consumption has been reduced to 3 k. g. (6.6 lb.) per ton of pig iron. The cost and time required for repairs were items which could not be estimated beforehand. Experience has shown that both the cost and the time required are less than could have been hoped for. Wherever employment for the gas can be found, this should also be taken into account, as is being done at Hagfors, where its value for firing the open-hearth furnaces is estimated to reduce the cost of the pig iron by about 66 cents.

With respect to *copper smelting* in the electric furnace, reference is made to the same authors' recent Am. Inst. Min. Eng. paper on this subject (see our September issue, p. 522).

The smelting of straight *lead ores* in the electric furnace has never been attempted either commercially or on a large experimental scale, largely because of the ease and cheapness of smelting by combustion processes. For the smelting of ordinary lead ores it has no especial application, but in the treatment of complex lead-zinc-silver ores the electric furnace, might be profitably used. The roasted ore could be treated in an electric furnace operated at a temperature such that the lead reduced by carbon melts and collects the precious metal values and the zinc is volatilized and condensed.

The use of the electric furnace in the metallurgy of non-ferrous metals has had greater application for the treatment of *zinc ores* than in the metallurgy of any other of the non-ferrous metals except aluminium and ferro-alloy manufacture. Since 1885, when an electric furnace for the treatment of zinc ores was patented by the Cowles Bros., experimental work has been conducted on the subject. The commercial application of the process, however, has not resulted to any great extent because of the difficulty of condensing the zinc vapor produced under the smelting conditions of the electric furnace. The cause of this difficulty has not yet been definitely determined. With few exceptions the experimental work has not been conducted on a very large scale, and so it may be said that the electric smelting of zinc ores is still in the experimental stage.

Undoubtedly the electric furnace has a very promising field in the metallurgy of zinc, but before its wide application can be expected the condensation problem must be solved and mechanical problems in connection with the electric furnace worked out. The latter should not be difficult. The special field for electric furnace work in zinc metallurgy is due largely to the low thermal efficiency of the present zinc retort which is given by Richards as only 7 per cent.

With the efficiency of the electric furnace varying from 50 to 75 per cent, the difference in the heat necessary for carrying out the smelting operations is so great as to permit of a higher cost of electrical energy than is permissible in many electrometallurgical operations.

The authors review the present methods of zinc smelting and compare therewith the electric furnace method of zinc smelting. They summarize the results obtained in commercial operation at Trollhättan, describe the experiments made by A. Stansfield and W. R. Ingalls at McGill University, refer to the experimental work of W. McA. Johnson, discuss the electric smelting of zinc sulphide ores with iron as desulphurizing agent, and then sum up the present status of electric zinc smelting as follows:

"The process is still largely in the experimental stage. There is no plant operating on a commercial scale except the Trollhättan works, taking from 7500 to 10,000 kilowatts. The experimental work mentioned is still going on, but as yet none of it has developed into a commercial operation.

"From what has been said concerning the work at Trollhättan and the results of others, it is very evident, as previously explained, that the difficulty lies almost entirely in condensation of the zinc vapor to a metal rather than blue powder under the peculiar conditions of the electric furnace. The electric furnace, mechanically or electrically, presents no great difficulties to solve, because all the troubles formerly experienced have been solved in the construction of large pig iron, steel, carbide and ferro-alloy furnaces. The problem, then, is one of a metallurgical nature, and is caused by the different conditions and greater speed of smelting in the electric furnace than in the combustion retort.

"The opponents of the electric smelting of zinc ores, who as a rule appear to have no knowledge of the great development of the electric furnace itself in the treatment of other ores, often state that, while the retort is the weak part of the old system, so is the electrode the weak point of the electric method. Admitting that the retort is the weak part of the retort method, and judging from large scale electrometallurgical work on other ores, we do not believe that in general the electrode is an exceptionally weak part of electric smelting. The electrode problem, no longer a serious one, has been solved in iron smelting. It is only fair to assume that the designer of an electric zinc furnace should stand upon the accumulated knowledge and take the results of others when the metallurgical problems of electric zinc smelting have been solved. One editorial writer in the *Engineering and Mining Journal* of December 14, 1912, goes so far as to say, in reference to retorts and electrodes, 'nobody can say which will be the weaker.'

"While it is not the purpose of the writers to enter into a discussion of the relative advantage of processes, it may be of interest to present a few comparative facts regarding retort and electrode consumption.

"Ingalls[4] states that the average life of a Silesian retort over a period of ten years is 38 days. One charge is smelted per day. An editorial in the *Engineering and Mining Journal* of December 14, 1912, states that the Silesian retort takes 200 pounds of ore per charge. Hence a retort treats 7,600 pounds or 3.8 tons of ore. Ingalls[4] also states that a condenser lasts from 8 to 12 days, so that about four condensers are necessary for the ore smelted by a single retort. He also states that a seasoned retort is valued at 50 cents, and a condenser at 4 cents. Thus the cost of a retort and condensers for smelting 3.8 tons of ore is 66 cents, or 17 cents per ton of ore smelted.

"At Trollhättan, Sweden, the electrode consumption has been reduced to 6 pounds (3 kg.) per ton of pig iron produced. Considering that two tons of ore were charged for each ton of pig iron produced, the consumption per ton of ore is 3 pounds. The smelting conditions in electric iron reduction would not tend to be as strongly reducing as in the zinc retort, although the ore in each case would be an oxide. Hence it may be expected that the total consumption of electrodes in a large, properly designed zinc furnace would not exceed 3 pounds per ton of ore.

"There is no longer loss of electrode because of unconsumed ends, as this loss has been entirely overcome by joining both amorphous carbon electrodes and graphitized electrodes. This reduces the loss by one-half.

"In some experiments by the writers on a mixture of sulphide and oxidized copper ores, with no carbon in the charge, and the charge proportioned so as to contain 15 per cent sulphur, the electrode consumption with air blown into the furnace for partial pyritic smelting was only 2 pounds per ton of ore. However, the furnace was designed so that the charge protected the electrode from the air.

"Amorphous carbon electrodes can be obtained at from 3 to 4 cents per pound, so that, on a basis of a consumption of 3 pounds per ton of ore, the electrode cost would be from 9 to 12 cents as compared with a retort cost of 17 cents. These figures seem to show that, rather than 'nobody can say which will be the weaker,' the retort at the present time is the weaker.

"If the failure of the electric furnace in smelting zinc ores is not due to the electric furnace or the electrodes, what then is the metallurgical condition which causes condensation difficulties and has retarded the commercial application of the process? The difficulty is, of course, due to a difference in the smelting conditions of the electric furnace as compared with the retort. Both physical and chemical conditions influence the formation of blue powder. Some powder forms under certain

[4] W. R. Ingalls, The Metallurgy of Zinc, p. 545 and p. 242.

conditions of pressure and temperature. As to just what these conditions are has not yet been solved. It is a problem for the physical chemist.

"The chemical conditions leading to the formation of blue powder are due largely to the speed of reduction of zinc oxide in the electric furnace and to the presence of volatile impurities in the charge. Boudouard found that the permissible percentage of carbon dioxide in the zinc retort was very low, and that when the limit is exceeded the carbon oxidizes the zinc, causing formation of blue powder. The vapor of the zinc retort is usually below this limit or not much above it, so that the zinc is condensed chiefly as liquid zinc. But in the electric furnace the temperature directly beneath the electrode in either the arc or resistance furnace is so high that the reduction proceeds so rapidly that the large amount of carbon dioxide formed does not have a chance to be reduced to monoxide by the hot coal of the charge before entering the condenser. Hence there is the oxidation of the zinc mentioned.

"By the use of electrodes of large cross-section it is probable that this concentrated heating could be reduced so that, rather than a very high temperature at one place, there would be a uniform comparatively low temperature all over the charge. This was found to be the case in the smelting of iron ores, both at Héroult, California, and Trollhättan. Or the current could possibly be distributed more evenly by flat electrodes of rectangular cross-section.

"The formation of blue powder is also caused by volatilization of silicon, which condenses on the zinc either as silicon or silica. For example, in some experiments at the Bureau of Mines Laboratory the condensed fumes from a ferro-silicon furnace contained 67.69 per cent SiO_2, 9.72 per cent Al_2O_3, 4.11 per cent FeO, 0.20 per cent MgO, 1.90 per cent CaO, with the rest carbon. This volatilization of silicon occurs in any electric furnace operated with an arc, as in ferro-silicon manufacture, when there is silica in the charge. At the lower temperature of a resistance furnace it is not so likely to occur.

"The solution of this problem is very probable, and, while it is difficult, there is no reason why it should not be worked out in time. When this is solved, and it is not necessary to resmelt a large proportion of blue powder as at Trollhättan, where two tons of blue powder are smelted for each ton of ore treated, it is probable that electric zinc smelting will proceed rapidly. The use of iron as a desulphurizing agent does not seem to have advanced as far as reduction of the oxide with carbon, and it is probable that the latter will keep its present supremacy. Some work has been done in an electric furnace operated under pressure or vacuum, but only a beginning has been made in this direction."

As to the treatment of *complex sulphide ores*, the authors speak as follows: The electric furnace has a possible field in Western metallurgy at places where there are complex sulphide ores of lead, zinc, copper, gold and silver. With the solution of the zinc condensation problem it is not unreasonable to suppose that the ores of this class can be electrically smelted so as to get a fair recovery of the metals and at least the precious metal values. Also, owing to the fact that practically as high a temperature as desired may be obtained in the electric furnace, it would be possible to smelt complex ores which have high gold and silver values, but which are too low in base metals, such as lead and zinc, to make their recovery worth the additional expense of concentration.

In the blast furnace 10 per cent of zinc in the charge causes sticky slags, and with a much higher percentage the operation of the furnace is very irregular and difficult. These slags could be fused readily in the electric furnace. In such a case, if the ores contained copper and zinc, the ore could be charged into an electric blast furnace using matte as a collecting agent for the gold and silver.

In the smelting of *gold-silver ores* carrying no lead or copper, to form either a lead bullion or a copper matte, but containing iron sulphide, the electric furnace might be used in connection with an air blast for oxidation of the iron sulphide, and an iron matte as a collecting agent for the gold and silver. The value of iron matte as a collecting agent is still largely a matter of personal opinion, but from the pyritic smelting which has been done with iron as a collecting agent, and from some experiments of the writers, using iron matte in the electric furnace, it is evident that a fair recovery can be made in this way. As in the case of electric copper smelting, the electric furnace treatment of these ores is still in the speculative stage.

Mines in isolated districts, where fuel is usually high and where the power operating the mine or mill is often hydro-electric power, could in many cases melt their cyanide precipitates more economically in electric furnaces than in combustion furnaces (as is done in Chihuahua, Mexico). The construction of a small Siemens type of furnace is simple and inexpensive. By operating the electric furnace when one of the units of the mill was down for repairs, or on the mine shift when little hoisting or drilling was being done, no additional electric installation would be necessary. This simply means that power which under ordinary conditions is wasted would thus be utilized.

On the treatment of *chromium, tungsten, molybdenum, and vanadium concentrates*, the authors speak as follows: The treatment of these ores is of particular interest to the Western metallurgist, for all of these ores are mined in the Western States, but their treatment has been confined to concentration by ore dressing or chemical methods, or shipment of their concentrates to the ferro-alloy manufacturer or the metal refiners. If these concentrates could be treated locally they would be given a "form value" at once, and thus enable the district in which they are produced to retain money which is now expended for freight charges, and also to retain the profits of the ferro-alloy manufacturer, which, because of the specialty of the product, are rather large.

For this work relatively high temperatures are required, so that the operation could not be performed metallurgically or economically in a blast furnace, reverberatory furnace or crucible. Tungsten is reduced from the trioxide at a temperature of 1500° C., and vanadium from the vanadate of iron or calcium at about the same temperature. The melting point of tungsten is 2800° C., molybdenum 2000° C., and vanadium 1750° C. All of these temperatures are high compared with that for the reactions usually performed in combustion furnaces. Of course, the melting point of the ferro-alloy would not be as high as that of the pure metal, and becomes lower with increased percentage of iron. The electric furnace is especially fitted for the smelting of rare metal ores to produce ferro-alloys because of the ease with which high temperatures were maintained.

The present status of the manufacture of *ferro-alloys* in the electric furnace is briefly considered, together with the reasons why the growth of this industry has been more slow in America than in Europe. The general construction of electric ferro-alloy furnaces is discussed as follows:

In general, an electric furnace for ferro-alloy manufacture consists of a crucible without a roof, having either a conducting or a non-conducting hearth and an upper vertical carbon electrode or electrodes. Most of the furnaces first built had a conducting hearth, and this practice is still common in furnaces up to 750 kilowatts capacity, but for larger sizes experience has shown the non-conducting hearth type to be preferable. One reason for this is because there is considerable loss of electric energy by dissipation through the lining, and hence there is a tendency to have a lower power factor. In working a small furnace intermittently, *i. e.*, discharging completely before charging again, the conducting hearth furnace is much easier to operate and start cold. When a large furnace is to be operated for several months continuously on one alloy, this advantage of the conducting hearth is of no importance. A factor which has been little considered in the construction of ferro-alloy furnaces is the power factor, as they are generally completely enclosed in sheet steel, when bands would do as well, with much less induction resulting in the circuit.

The ferrosilicon furnaces are lined with carbon, while the furnaces to be used in producing other alloys are generally

lined with a basic lining of magnesite or dolomite brick or a mixture of tar with either material. When low carbon ferrochrome is being made the lining is sometimes chromite. Generally a furnace is designed so that the electrode or electrodes are at a sufficient distance from the sides to permit a chilling of the material charged upon the walls. This has been found to give the most satisfactory lining. Under such conditions furnaces have been operated for two or three years without being relined. The average furnace operated continuously runs about two years before being shut down for repairs. A furnace operated intermittently must, of course, be relined more often.

Owing to the greater part of the reduction of oxides in ferro-alloy manufacture being done at high temperature by solid carbon, most of the furnaces are run with an open top, into which the charge is placed around the electrode. Under these circumstances there is a considerable waste of heat which might be used in preheating the charge. In these furnaces the electrode usually dips about 12 to 15 inches beneath the top of the furnace, which is kept filled with cold material so as not to expose the molten mass beneath. There is burning of carbon monoxide around the electrode, and an escape of a large volume of gas through the top of the furnace house. It is stated that one of the Alby type of carbide furnaces is operating with a closed top at Kopporaaen, Norway. The Helfenstein furnace does away with the open top also, as it is air tight, and in addition has feeding shafts where the charge is preheated by the waste gases. In the manufacture of the higher-priced alloys, such as ferrotungsten, it is impossible to use any furnace but one with an open top, because of the intermittent nature of the operation, but in making ferrosilicon and ferrochrome it seems advisable to preheat the charge as much as possible and prevent as much oxidation of the electrodes as is possible in this manner.

A large number of the first ferro-alloy furnaces were supplied with direct current when the furnace house was built adjoining the power house, so that there was only about 20 feet between the furnace and the generator. It was soon found that the electrolytic action in a direct-current furnace resulted in deposition of potassium, sodium, calcium, aluminium with the alloy so that as pure a product could not be obtained with direct as with alternating current. When alternating current was first used, single-phase current was the more common in general application, so that the arrangement remained the same as previously, the generator delivering directly to the furnace at the desired voltage without any transformation.

Later, when three-phase current became prevalent, furnaces designed to take single-phase current were connected in groups to three-phase systems by several methods. Then the single phase furnaces were replaced for large scale work by the present-day three-phase furnace.

The *cost of electric power* for electric furnace is finally considered and figures are given for the production of electric power with gas engines and steam turbines.

"As to what the cost of power produced by gas engines would be, a reliable engineering concern has furnished data which show that, with coal at $3.00 per ton, which it is assumed will contain 13,000 b.t.u. per pound, electric power can be produced at about the following cost when using gas-engine-driven generators at a load factor of 75 per cent:

Size of Plant, Kilowatts	Cost of Power in Cents per Kilowatt Hour, Coal at $3.00
2,000	0.745
4,000	0.687
6,000	0.649
8,000	0.637
10,000	0.633

"These figures include operating costs and fixed charges.

"The same engineering concern has also supplied the writers with data in regard to the cost of electric power produced by steam-turbine-driven generators. Based upon this data, the cost of electric power is shown in the following table, with coal at $3.00 per ton. These costs include operating costs and fixed charges, and, as before, it is assumed that the coal has a heating value of 13,000 b.t.u. per pound and that the load factor is 75 per cent."

Size of Plant, Kilowatts	Cost of Power in Cents per Kilowatt Hour, Coal at $3.00
2,000	0.688
4,000	0.597
6,000	0.532
8,000	0.526
10,000	0.514

A table is finally given of the approximate cost of power at various electrochemical plants in various countries. The prices range all the way from $5 per kilowatt year (Rjukan, Norway, for nitrate manufacture) to $110 per year (Braintree, England, for electric steel making).

The paper elicited a spirited discussion.

In a communicated discussion by Mr. F. A. J. Fitzgerald, the scope of the work of the U. S. Bureau of Mines was criticized.

Mr. Lyon, in reply, stated that the work of the Bureau was to ascertain facts and make the public acquainted with the facts. He welcomed constructive criticism of the work of the Bureau of Mines by the American Electrochemical Society. A committee specially appointed for this purpose could render useful service.

Professor Richards stated, unofficially, that Director Holmes was desirous of having such a committee appointed in order that his Bureau might work in full harmony with the national societies in investigating questions of national concern in the various fields of science coming within the purview of the Bureau. Professor Richards moved "that the Board of Directors be requested to appoint a conference committee authorized to confer with the Director of the Bureau of Mines regarding the activity of the Bureau in electrochemical and electrometallurgical matters."

Mr. F. A. Lidbury seconded this motion, which was then unanimously carried.

Dr. Richards, in discussing the paper, said that electric zinc smelting was no longer on the experimental scale. There was a new plant now in operation at Helsingfors, in Finland. At present 2500 h. p. are used, but the plant is to be enlarged to 6000 h. p. But the United States is behind Europe in this development. As to the idea of some electric zinc men that electric zinc smelting was chiefly an engineering problem, this was quite erroneous; the chemical and metallurgical problems must remain in the foreground.

Mr. C. A. Hansen discussed at some length the possibilities of electrochemical methods in the West. He also emphasized the excellent prospect of electric steel casting plants. He gave a set of very interesting figures, favorable to the electric furnace, in comparison with the acid open-hearth, the Tropenas converter, and the crucible. As these figures, based on the experience of several years in large-scale operation, were given by Mr. Hansen from memory, we reserve their publication for a future issue, when the figures will have been verified by Mr. Hansen and given out authoritatively.

Dr. John A. Matthews, of the Halcomb Steel Co., said that while in Scandinavia and California the electric iron ore reduction furnace had made rapid and important progress, yet in the Eastern States of this country the possibilities of the electric furnace in the iron and steel industry were chiefly in three directions: first, for the production of high-grade steel; second, in combination with the Bessemer converter for large tonnage products; third, for steel castings. This third field was probably very important.

Mr. E. L. Crosby of the Detroit Edison Company spoke of possibilities of electric furnace loads for central stations.

Mr. L. B. Skinner emphasized the comparatively high cost of electric power in the West. In Denver no power could be had at such a price as 1 cent per kw. hour. This fact had to be considered in connection with electrochemical schemes in the West. Further, the cost of labor is high. He referred to an extended trip of a distinguished Western metallurgist to Europe

to study the status of electric zinc smelting there not so long ago; he had not found that the problem had been solved commercially.

Owing to the lateness of the hour the discussion had to be interrupted. It was, however, taken up again the next day in connection with the two electric zinc papers.

Session in Golden

The third technical session was held in the School of Mines at Golden in the afternoon of Thursday and was probably the best attended session, there being nearly 100 members and guests present.

Mr. McGregor presented his paper on electrostatic concentration and Dr. Lind his paper on the transformation of radiant into chemical energy. The two electric zinc papers, one by Mr. Johnson, the other by Mr. Petersen, were next presented and discussed at considerable length. On account of the lateness of the hour all the other papers were then read by title and briefly discussed.

Progress in Electrostatic Ore Dressing

The paper by Mr. **Frank S. MacGregor** on this subject attributes the continued success of the electrostatic concentration process (Huff process) to three factors:

(1) Use of electricity produced by commercial electro-magnetic generators and transformers, whose output and potential is steady and capable of easy regulation in the place of the very erratic frictional static machines which were formerly tried.

(2) Use of concentrated and powerful electrostatic field by means of two adjacent electrodes, giving steadiness and strength to the action.

(3) Use of a grounded machine constructed almost entirely of metal, and therefore free from electrical disturbances.

A review is given of the use of this process and the results obtained at the following plants: U. S. Smelting, Refining & Mining Co. at Midvale, Utah; Calumet and Sonora Mining Co. at Cananea, Mexico; Sunnyside Mines in Eureka, Colorado; Mary Murphy Mine at St. Elmo, Colorado, and a custom zinc plant at Ouray, Col.

Zinc smelters pay a much better price for a high-grade zinc concentrate than for a lower one, even if the impurity is only gangue, and it is not always feasible to remove all this gangue on the ordinary wet tables without entailing too great a loss of zinc. At the latter plant an interesting electrochemical action has been utilized to raise the percentage of zinc in the zinc product.

Ordinarily a crystal of zinc sulphide is a non-conductor, a characteristic which enables the separation just described to be made, but, if the crystal be immersed for a short time in a very weak solution of copper sulphate, it becomes coated with a film of copper sulphide. This is an excellent conductor of electricity (speaking electrostatically) and if the particle is dried at a moderate heat, it behaves as a conductor, and is repelled by the electric charge in the same manner as pyrite, chalcopyrite, graphite or other conducting minerals. Separations of zinc sulphide from gangue have been made in this way on a laboratory scale for some time, but the method has been utilized commercially for the first time in the Ouray plant.

The treatment is very simple: the zinc product is run into tanks, covered with a 0.5 per cent solution of copper sulphate, allowed to stand for a short time, the solution then drawn off for further use, the ore then dried and on passing through the electrostatic separators a 40 per cent zinc product is raised to 51 per cent with only 5 per cent zinc remaining in the gangue product, making a recovery of 97 per cent. The consumption of copper sulphate is very small, a new solution treating several lots.

Besides the zinc field other fields are now being entered by electrostatic concentration. Excellent work in the concentration of crude silver ores has been done in a 30-ton mill in Austin, Nevada.

In Australia a Huff plant concentrates molybdenite from its gangue.

Two graphite mills now employ this method for removing the mica from the graphite flake, the solution of a very vexing problem. It is not improbable that the entire concentration of some graphite will be done electrostatically.

A recent development of great importance, both to the process and to the industry it affects, if the present indications are borne out, is for the cleaning of coal, both anthracite and bituminous. With anthracite occurs slate and other impurities which in the finer sizes are very difficult of separation. Electrostatic separation has offered a solution for this problem, reducing the ash in the "culm" from 25 to 30 per cent to 10 or 12 per cent.

In bituminous coal, the problem consists in the removal of ash and sulphur. Sometimes most of the sulphur present is "organic," so associated with the carbon that it cannot be mechanically removed, but when the sulphur is present as "pyrite" or in "bone," it is readily repelled, and with its extraction comes a large reduction of the ash. Activities are just entering this field.

ON TOP OF PIKE'S PEAK

A typical mill flow sheet for an electrostatic plant consists of a cylindrical dryer, about 4 ft. x 20 ft., made of sheet iron; bucket elevator to the top of the mill, carrying the dried ore to the screens. In some cases only a "scrap" screen is needed if the sizing required is 20 to 50 and through 50 mesh. If the various minerals will break mechanically free above 20 mesh, one or two coarse screens are necessary, as 6 to 12, 12 to 20 mesh. Then the ore is taken to the separators, through which it falls by gravity, the conductors and non-conductors as separated passing directly to storage bins. Returning a small amount of middlings from each separator back into the system is beneficial in increasing the tonnage and making cleaner products. These middlings finally pass out of the system in the finished products.

The power required is small, a 3-hp generating outfit being sufficient to electrify a plant of from one to fifty separa-

tors. The machinery of one plant is operated by 12 actual hp, which includes power for the dryer, elevator, screens and six separators. One attendant will care for a shift, exclusive of handling ore.

In conclusion the author said that while the installation of electrostatic separators has not been as rapid as the exploitation of some other metallurgical processes, it has developed a unique field of its own, to which no other process is as well adapted, and the tonnage treated electrostatically is steadily increasing.

The paper was discussed by Mr. G. E. Collins, who gave interesting details of the result obtained with electrostatic concentration at one of his mines and compared it with electromagnetic concentration.

The Transformation of Radiant Into Chemical Energy.

A paper by Dr. **S. C. Lind,** of the Bureau of Mines, gave a summary of a continuation of his theoretical and experimental researches in this field. The results are summed up as follows:

Much experimental evidence is now at hand in support of the principle of electrochemical equivalence in gas reactions taking place under external ionizing agencies.

The use of the term "applicability of Faraday's law to gas reactions" may lead to confusion, especially in the case of reactions produced by electrical discharge, in which the measured current does not correspond directly to the quantity of chemical change. The term ionic-chemical equivalence in gas reactions seems preferable.

The theoretical maximum amount of ozone producible per hour by one gram of radium in equilibrium is estimated to be about 0.72 gm. Warburg's premises by means of which he estimated a lower value are discussed and the sources of error pointed out.

A method is shown by which the coefficient of the transformation of (ionizing) radiant energy into chemical energy may be calculated from the N/M ratio (where N is the actual number of pairs of ions produced and M the number of molecules entering into reaction).

For several *endothermic* reactions the transformation factor is shown to have the low average value of about 2 per cent, the same as has been found for some reactions produced under other forms of radiant energy.

The ratio of chemical to radiant energy in *exothermic* reactions is of the same low order, indicating that the influence of the free chemical energy in these reactions when produced by ionizing agencies, is very subordinate in importance, if it exists at all.

The paper was discussed by Professors Frary and Schoch.

The Art of Electric Zinc Smelting

Mr. **Woolsey McA. Johnson's** papers on this subject begins with a frank statement that "strictly speaking, there is no art of electric zinc smelting, for the commercial trials in this country, Canada and abroad have been clever, but are not art, since none of them are pronounced commercial successes.

"Our ideas and practical embodiment thereof are radically different from previous commercial attempts. We are not, however, claiming anything more than our personal faith in our ability to operate our process on zinc-lead-copper ores, recovering spelter, base-lead bullion and copper matte in one operation at a probable handsome profit under certain conditions. It is evident that the only criterion of a successful new process is the actual production of finished product at a profit for the market under actual commercial conditions."

The author quotes from an old report of his own, made in 1904, that the weak points of the present method of treating zinc ores are high labor charge per ton of ore, high fuel cost per ton of ore, and low recovery from even high-grade ores with restrictions as to nature of ores, while the advantages of a commercial electric zinc furnace would be large units, higher thermal efficiency, ease of control over smelting and production of pure spelter from impure ores.

Mr. Johnson then points out some of the inherent difficulties of the problem. ". . . This very friendship of electricity and zinc is seductive, for any experimenter with 20 kw at his disposal, a few firebrick, some zinc ore and a couple of carbon electrodes cannot help making some zinc, only a few pounds, to be sure, but enough to allure him to further pursuit. And the very contrariness of the metal that seems to have so much free-will is that if one tries to make 100 per cent of zinc vapor as commercial zinc-dust, one will fail. For zinc is a peculiar metal.

"All our attempts up to 1909 were concentrated on the condensation of zinc vapor to spelter. We were correct in the statement, I believe, that we knew seven or eight years ago that the main conditions for good condensation were as follows:

"1. A regular flow of *pure* gas.

"2. Space at right temperature.

"3. Sufficient time."

The author discusses the production of blue powder instead of liquid smelter and distinguishes between "chemical" and "physical" blue powder (see this journal, Vol. 10, p. 451) and says that there are a number of conditions which produce chemical blue powder and that all but three of them can be easily prevented by foresight, provided their causes are known. In one of the tables in the paper giving the results of some of his last year's work it is seen that on complex ores, high in FeO and analyzing 4 per cent S the author has exceeded the condensation factor of 50 to 70 per cent, obtained in retort practice on simple ores well roasted.

The author sums up the requirements of successful electric zinc smelting as follows:

1. A first-rate preheater, mechanically strong and machine operated. Preheating *per se* has no advantage save to reduce kw hours per ton of ore. Preheating must be done right, not too hot, not too fast, not too slow, and not too cold, with a progressive application of metallurgical means.

2. The flow of heat through the charge in the electric smelting furnace and slag must be under perfect control. The electricity must be controlled, and care must be taken that the zinc globules in eductor assume no statical charge, otherwise coalescence of the sphericles is hindered.

3. A regular flow of pure zinc gas must be delivered at proper temperature to the condenser.

4. The condenser must be durable and under good metallurgical control.

When all these conditions are fulfilled, spelter will come as a result of continuous electric zinc smelting in surprising amounts.

"The present Johnson zinc smelting process depends commercially upon the by-products. Furthermore, there is no doubt that our recoveries of lead, copper, gold and silver will be much higher than those of a lead furnace or of a copper furnace.

"Our general proposal is to treat low-grade ores high in by-product values. While we have treated oxidized ores, as Joplin 70 per cent zinc or even oxide of zinc, at the plant of the Continuous Zinc Furnace Company, we prefer to use low-grade ores analyzing about 35 per cent zinc.

"It seems distinctly probable that the cost of treatment of the zinc ores in the Johnson electric zinc furnace will be roughly inversely proportional to the percentage of contained zinc. Our process, therefore, will have quite an influence on the concentration of zinc ores and utilization of crypto-crystallic ores which are now commercially unavailable. It is thought by us that the general tendency, when we are successful in our commercial trial, will be to shorter and more direct concentration with as much of the Cu, Zn and Pb in one concentration as is possible. Lead smelting and copper smelting with low rate for power will be as cheap or cheaper in the Johnson furnace than in the ordinary lead or copper furnace because of the increased recoveries, provided metals stay at average prices. The relation between concentration and smelting will be different. It looks as if what the Johnson process needs were zinc-iron middlings with considerable included

galena for maximum commercial efficiency, though, of course, existing concentration methods will also be applicable. We see that the general commercial conditions governing grade of ore are diametrically opposite in the Johnson process and in the retort process, where, with the exception of dry carbonate zinc ores, the cost of treatment increases as the grade of ore treated is lowered. Metallurgical needs of the Johnson process are for fluxing ores high in lime and iron." . . .

"While I hesitate to disagree with Mr. Ingalls, who has studied so long on zinc problems, yet when he says that, 'if there be any dreams of an electric furnace analogous to a blast furnace in which run of mine ore may be charged roughly and from which spelter, lead and perhaps also copper matte may be obtained concurently, I fear that there will be no realization of them.' I take issue direct with him. He, in my judgment, is not unqualifiedly wrong, but qualifiedly wrong. The success of our process will come at first because the Johnson furnace is similar and analogous to a lead blast furnace.

"The use of ZnO prepared by a fired process from low-grade sulphide ores in an electric furnace does not appear especially attractive, for we had the idea of igneous concentration of zinc ores making zinc oxide on apparatus similar to Wetherill grate in 1908 with subsequent electric smelting of ZnO so produced, but put aside the idea. However, the Truax process for manufacture of zinc oxides out of slags has, to my notion, certain brilliant possibilities and is a triumph of American originality. It certainly looks good. The Betts process, using silicon as a reducing agent, has decided possibilities. Consideration of wet or hydrometallurgical processes for zinc ores is useless. Their metallurgy is complicated, plant expensive, and cost of treatment high and uncertain. Quantitative analysis writ larger does not spell metallurgy. High recovery may some day bring them to life, but only at the time when every Italian laborer knows as much as a $1000-a-month chemist. Their only chance, and that a remote one, is for very low-grade ores containing an insoluble gangue."

Mr. Johnson thinks that his particular problems are those of an engineer rather than those of an inventor and gives a number of tables of runs in his furnace during the last year. (Since the tables printed in the advance copies of the papers contained numerous numerical errors, the reader must be referred to the corrected tables which will appear in the *Transactions* of the Society.)

The "accounted zinc factor" in three runs (leaving aside a fourth run with a split condenser pipe) ranged from 80.5 to 81.9 per cent, the condensation factor from 77.8 to 81.5 per cent. The "accounted zinc factor" is defined as the ratio of weight of zinc accounted for in all produts to weight of zinc delivered to electric furnace. The "condensation factor" is defined as the ratio of weight of zinc in spelter produced to the sum of weight of zinc in flue dust plus weight of zinc in ladle skimmings plus weight of zinc in blue powder plus weight of spelter.

In the same three runs the kilowatt hours per lb. spelter varied between 3.10 and 3.74, the kw. hours per short ton of preheated charge between 1452 and 1748, the thermal efficiency (estimated in two ways) between 33.8 and 41.4 per cent, the total electrode carbon consumption per 1000 kw. hours between 5.57 and 8.25 pounds. The spelter made was sold to a brass founder in Hartford.

"Our aim in these tests, basically considered, was to attain a condensation factor higher than retort practice. I estimate the maximum average yearly condensation factor attained in retort plants in the United States at 65 per cent. Many retort plants in this country, however, have a condensation factor of less than 60 per cent. Of course, the mixture of ores used at our Hartford experimental plant is not metallurgically or commercially possible in retorting practice.

"At our Hartford plant we have mastered condensation on an experimental scale, for some of our best condensation has been with refractory ores." . . .

"Mr. Ingalls, in his extremely clear article, speaking of the claims as regards power consumption, states: 'While it is doubtful whether such a result has yet been actually realized by anyone, the claim is plausible with respect to certain kinds of ores, although even then it is necessary to assume a high furnace efficiency. It would seem that 1200 kw. hours per 2000 pounds of ore would be a sufficiently brilliant realization. Even such a one would put electric zinc smelting upon a sound basis in so far as power consumption is concerned. It is curious to note that 1200 kw. hours given by Mr. Ingalls as lower probable limit is upper probable maximum limit of power consumption which I have set down for 35 per cent zinc ores. Actually we have bettered this figure, and 600 kw. hours for a 35 per cent zinc ore does not seem to be impossible.

"With a glance at the future, and basing our reasoning on our own progress in the past three years, and extrapolating this progress, the prediction is hazarded that electric zinc-lead smelting will have a treatment cost of as low as $6.00 per ton of ore, and that the losses exclusive of roasting losses will be: Zinc 40 pounds, lead 1 pound, copper 2 pounds, silver 0.30 oz., gold 0.01 oz., per ton of ore. This is for the ultimate future. For the immediate future multiply this estimate by two and we have a safe estimate of what can be done."

Mr. Johnson's paper elicited quite an extended discussion. Dr. Richards emphasized as one of the principles of the Johnson process the preheating of the charge so as to remove water vapor and reduce the reducible oxides (iron) with the carbon without reducing the zinc. He also said that Mr. Johnson had paid special attention to the treatment of complex ores, such as are not treatable with the retort process, like Bully Hill ore. But it may be questioned whether it would not be better to begin with simplest ores.

Mr. E. J. Ericson criticized briefly some special points in Mr. Johnson's paper and asked whether the claim of a condensation factor as high as 80 per cent was not a misprint, since others, like DeLaval, had not succeeded in condensing any such percentage as this as liquid zinc. Dr. Roeber said that it was not a misprint, but that according to Mr. Johnson the condensation factor in his more recent work was 80 per cent or more. This was confirmed by Dr. Richards, who said that in the DeLaval furnace the zinc vapor was overheated, which caused condensation difficulties.

Mr. C. A. Hansen took up some points of the discussion of the day before. He thought the electric furnace was not suitable for all zinc problems. He also emphasized that the development of the electric furnace had been held back for several years by superficial statements of men who knew or should know better.

Mr. F. S. MacGregor discussed electrostatic separation in zinc metallurgy, with reference to the discussion, by Mr. Collins, of his own paper.

Mr. L. B. Skinner reviewed and criticized Mr. Johnson's paper at some length. He thought that the paper was incomplete and that the tables did not give sufficient data. He also emphasized that the development of a new process should be carried out in such a way that the simplest problems were first solved, beginning with chemically pure materials. He agreed with the author that hydrometallurgical processes were not promising for zinc.

This latter remark induced Mr. John L. Malm to speak briefly on his own process. A paper on this subject is expected to be presented at the next meeting of the Society.

After a few more remarks by Professor Clevenger and Professor Richards the discussion was closed and the second electric zinc paper, by Mr. Peterson, was taken up.

The Electric Zinc Furnace

The paper by Mr. **Peter E. Peterson** gives a quite detailed description of the experiments which the author has made during the last years in Butte, Montana. The author describes in detail, with illustrations, the construction of the various electric furnaces and condensers which he has used.

In this last experiments the efforts at improving the con-

densers were temporarily abandoned and arrangements were made to recover all zinc products. To accomplish this a new furnace was built and special iron condensers were made to recover the blue powder; also a bag house was used to catch the zinc oxide in fumes.

A continuous twelve-day run was made without difficulties of any kind.

The charge was fed in every hour, and slag and matte tapped every twelve hours.

"This furnace in its present improved form is about all that can be expected of any furnace. There are far less difficulties encountered than in running an ordinary blast furnace. The deterioration of the furnace is small. Such a furnace should run from six months to a year without any extensive repairs. Large units can be constructed by merely the addition of more electrodes, and there is no reason why units of 25 to 50 tons each could not be operated as easily and cheaply as the one-ton units."

As to the metallurgy of electric zinc smelting Mr. Peterson says as follows:

"In the operation of the electric zinc furnace the composition and condition of the smelting charge is quite as important as the furnace. More care must be exercised in making up furnace charges than in ordinary blast furnace practice. The charge must be such that at all times there is a perfect reducing atmosphere in the furnace; the slag must be such that deterioration of the furnace lining is reduced to a minimum, and with a sufficiently high formation temperature to volatilize the zinc. A matte must be made that is uniform in composition and is readily tapped from the furnace, and made in sufficient quantity to effect a good saving of copper, gold and silver. The proportion and nature of the reducing carbon is important. As before mentioned, a perfect reducing atmosphere must be maintained, and at the same time the reducing carbon must be completely consumed. If an excess is added, it cannot be burned by an air blast as in blast-furnace practice, and the only oxygen available for its consumption is that held in combination by the constituents of the furnace charge.

"The physical character of the charge is quite as important as the chemical for the best work. The charge constituents should be finely divided so as to allow the various reacting elements to be in intimate contact with one another, thus insuring more perfect and economical results. But the charge must not be too fine when charging in loose rather than in brickette form. The particles should be of such weight or size as to readily settle from the zinc vapors and gases passing outward into the condensers. If the particles are too fine they are apt to find their way into the condensers in the unmelted condition.

"It is necessary to have the charge absolutely dry. The presence of water even in small quantities is serious, due to the oxidizing of the zinc vapor by decomposition of the water. What is still more serious is the instantaneous generation of steam and other gases, causing a great increase in the velocity of gases, thus disturbing the condensation of the zinc in the condensers and thereby causing a loss of zinc and also a loss of silver and other metals, due to furnace charge being blown outward into the condensers.

"If it is not possible to mix the charge with hot calcines from the roasting furnace and then immediately feed it to the electric furnace, there must be a preheating furnace to heat the charge before introducing it into the electric zinc furnace.

"The making of slags is governed by the nature of the furnace linings, and these are dependent on the nature of zinc concentrate or ore to be smelted. If the concentrates are high in iron and low in silica, then a basic slag high in iron is made, and consequently a basic furnace lining (such as magnesite brick) is used; and if the reverse is the case, then high-silica slags with silicious furnace linings are used.

"The principle used in the elimination of zinc from slags was to make slags of such high formation temperature as to practically volatilize most of the zinc before slagging of the charge begins.

"In silicious slags the high percentage of silica is the principal controlling factor. In basic slags the percentage of reducing carbon is increased, which for practical purposes gives the same effect.

"In the work I have been identified with we have had practically no difficulty in eliminating zinc from either basic or silicious slags. The degree of elimination depended on the quantity of power used. Following are analyses of slags showing how zinc elimination can be varied:

	Zinc	Copper	Iron	Insoluble	Silver	Gold
Slag No. 1..	0.3%	0.24%	16.1%	66.2%	1.2 oz.	trace
Slag No. 2..	1.6	0.13	19.2	57.5	0.6	trace
Slag No. 3..	5.5	0.47	22.9	45.5	4.1	0.01 oz.
Slag No. 4..	8.5	0.38	23.5	44.4	2.1	trace

"In the treatment of complex ores the other metals, gold, silver and copper, are also recovered. This is accomplished by producing a collector (matte) similar to the lead button in crucible fire assaying.

"In the earlier work it was attempted to use as a collector a matte consisting principally of iron sulphide, but its use was not attended by any degree of success. The matte formed was very irregular in composition, varying from metallic iron to iron sulphide. The amount of matte formed was also irregular, and it was found necessary to add copper ores until the furnace charge would assay in the neighborhood of 1 per cent copper in order to get a matte uniform in quantity and composition. The quantity of matte was varied by varying the percentage of sulphur in roasted zinc calcines. Zinc calcines were successfully treated that varied from 2 to 15 per cent sulphur. The best results were obtained between 5 and 7 per cent sulphur. One of the important reactions in this connection is:

$$Fe_2O_3 + 3C + 2ZnS = 2FeS + 2Zn + 3CO$$

or $Fe_2O_3 + 3C = 2Fe + 3CO$ and $2Fe + 2ZnS = 2ZN + 2FeS$.

"Coke was found to give the best results as reducing agent. When coals were used it was noticed that the condensing of the zinc was seriously interfered with, due to deposition of fine carbon or soot in the condensers from the decomposition of the hydrocarbons in the coal."

The author discusses briefly methods of treating blue powder to change it into liquid zinc, and the possibilities of the design of a more efficient condenser.

"Electric zinc furnaces constructed on the same principles of heating as retort zinc furnaces have given as good condensing results. In these furnaces the heating of the furnace charge is accomplished by the radiation of heat from an electric arc located above the charge. Practice has proven this a very inefficient means of electric heat, yet so far as condensing is concerned it gives the best results."

Mr. Peterson finally illustrates "a proposed condenser for electric furnaces that should have a large capacity and be effective in its operation. The principle of the condensing is to pass the gases from the electric furnace through a molten bath of zinc; the bath is automatically maintained at the right condensing temperature by being covered with a molten bath of zinc chloride which boils at a temperature which will not allow the molten zinc bath to get too hot. The passage leading to the molten zinc is heated to prevent any condensing and consequent clogging of the tubes.

"For the operation of this type of condenser the zinc vapors must be distilled under pressure; for observations made with this idea in mind there should not be any difficulty in maintaining a pressure of 2 pounds per square inch (0.13 kg. per sq. cm.), which should be sufficient to work this condenser.

"The quickest and most effective method of condensing any vapor to liquid is the one mentioned above. A good illustration of the method of condensing is the passing of steam into water."

An estimate, worked out on a one-ton unit, of the costs per ton of pay charge, is given as follows:

Roasting	$1.00
Supt. and Assay Office, etc.	1.00
Labor based on 33-ton plant	.83
Powder—1401 Kw. hours, at 0.332 cent	4.65
Depreciation of plant	.40
9.5 lbs. electrodes, at 14 cents	1.33
0.1215 ton coke screenings, at $5 per ton	.60
440 lbs. matte. Cost of marketing	2.86
Total cost	$12.67

"With the electric zinc furnace the following extractions can be depended upon for the above costs: Zinc extraction, 85 per cent; copper extraction with 5 per cent copper in charge is over 95 per cent, and with 1.5 per cent copper in charge is over 84 per cent; silver extraction, 65 to 72 per cent; gold extraction, from 98 to 100 per cent.

"The gold, silver and copper are recovered in the form of a copper matte. The difference in the value of the metals and that actually obtained from them is called the cost of marketing the matte.

"The zinc as obtained with the process at its present perfection of condensation with the above costs contains only 30 per cent spelter ready for the market. The remaining 70 per cent of the zinc is obtained in the form of an 80 per cent zinc product, as blue powder and some zinc oxide. This zinc as produced by the electric zinc furnace would be worth $4.36 a hundred pounds when spelter is selling at $5.50 per hundred, that is, when the 30 per cent spelter produced is placed on the market and the remaining 70 per cent of the zinc in the form of an 80 per cent product is shipped to zinc smelters on an ore basis treatment charge. Greater economies could be effected if the electric smelter had retorts of its own to treat this high-grade concentrate of blue powder and zinc oxide.

"If a straight zinc concentrate assaying 50 per cent zinc is shipped to a zinc smelter, the probable basis of settlement would be as follows: 85 per cent of the zinc content at market price of spelter, with $16 deducted for treatment charge. With spelter at 5.5 cents per pound, one ton of 50 per cent concentrate is worth $30.75.

"The electric smelter, after deducting $12.67 for treatment, would return for the same concentrate $23.41. But if a complex zinc concentrate containing approximately 10 per cent iron with copper, gold and silver values were to be considered, the difference would be greatly in favor of electric smelting. The penalties on iron, etc., and the poor extraction of copper, gold and silver by the retort smelters would make it impossible for them to compete with the electric zinc smelter.

"In the West complex zinc ores are abundant, and in some cases water power can be obtained near the mines, which would be an added advantage to the electric smelter by effecting a saving to the miner on freight on concentrates.

"Another probable source of increased revenue would be the sale of zinc products, as zinc oxide, for the paint industry. Statistics show that, in 1910, 16 per cent of all zinc produced in the United States was sold as zinc oxide, and in this form brought 0.1 of a cent more per pound than if sold as spelter. There is absolutely no difficulty in making zinc oxide suitable for paint by the electric furnace. The principal accessory required is a bag house and packing plant. A small percentage of the product could be sold as blue powder at prices about equal to that of spelter."

Mr. Peterson's paper was briefly discussed by Mr. Clevenger, Mr. Skinner, Mr. Ericson, Mr. Snow, and Dr. Richards. Mr. W. M. Snow, of the Illinois Zinc Co., said that in improved modern retort practice metal recoveries of 86 to 91 per cent were obtained. While the condenser of present zinc metallurgical practice had been evolved by try-and-hit-and-miss methods, it was nevertheless quite an efficient instrument.

Dr. Richards pointed out the following difference in condensation in retort practice and in the continuous electric furnace. In the former the condition of the gases is continually changing, in the latter it is constant. This difference may necessitate a very different design of an efficient condenser in both cases.

Electric Smelting of Chromium, Tungsten, Molybdenum and Vanadium Ores

The paper by **Robert M. Keeney,** of the Bureau of Mines, on the above subject first takes up the electric smelting of chromite and the production of **ferrochrome.**

The author discusses the reduction of chromite by carbon, silicon, aluminium, calcium carbide, further the available ores and raw materials and the process of manufacture.

The electric furnace used in the manufacture of ferrochrome may be one of several types, all of the principle of the Siemens crucible with a conducting hearth, or similar to the Héroult steel furnace, with vertical electrodes in series.

"The process of manufacture of ferrochrome consists of mixing a charge of chromite and anthracite coal in proportions based upon the theoretical calculations given. This is shoveled into the open top of the furnace around the electrodes. The furnace is charged at regular intervals so as to keep the top in a solid condition. The ore is very finely powdered, but the coal is about as it comes from the mine. There is some loss by ore being carried off with the gases which escape at the top of the furnace.

"The ferrochrome is tapped from the bottom, at intervals of from two to four hours, into iron pots set on cars, from which it and any slag are dumped when solid. The slag and metal come out of the same tap hole. When cold the metal is broken up with hammers to separate it from the slag and packed into kegs or boxes. For tapping an iron rod is used to open up the tap hole, which is plugged with fire clay.

"Ferrochrome manufacture is carried on continuously, in some cases for two years, before shutting down the furnace for repairs. In one operation, directly from ore, ferrochrome containing down to 5 per cent carbon can be made economically. It has been possible to produce an alloy containing as low as 2 per cent carbon in one operation, but great care is necessary in the regulation of the charge and the operation of the furnace. The slags from the average ferrochrome furnace making a 5 per cent carbon alloy run from 0.5 to 1.0 per cent Cr_2O_3."

The author then discusses the refining of ferrochrome. Decarburization of high-carbon ferrochrome is accomplished by melting the alloy with a slag of lime, chromite ore and a little fluorspar. Other methods of refining are briefly noted.

The author then describes some experiments made by him in 1912 on the production of ferrochrome from chromite with carbon as a reducing agent. The conclusions drawn are: "First, that ferrochrome can be easily manufactured directly from chromite in the electric furnace; second, that the percentage of carbon in the ferrochrome cannot be kept low by regulating the carbon charged without excessive loss of chromium in the slag; third, that the percentage of carbon in the ferrochrome must be regulated by decarburization with an oxide slag of iron or chromite after tapping off the slag from reduction; fourth, that silicon and phosphorus cannot be kept low in the alloy under the strong reducing conditions necessary; fifth, that sulphur can be easily slagged; sixth, that, as the addition of lime does not seem to aid in removing phosphorus, it is advisable to use no lime, but as pure raw materials as possible; and, seventh, that the power consumption should not exceed 3.7 kilowatt-hours per pound of ferrochrome tapped, or 0.85 kilowatt-year per ton. Some further notes on power and electrode consumption are added.

The author next takes up **ferrotungsten,** giving historical notes, theoretical considerations of the reduction of wolframite, ferberite or scheelite with aluminium, silicon or carbon, and describes the process of manufacture as follows:

"Ferrotungsten is manufactured from ores in three ways: First, by direct reduction with carbon in a crucible; second, by reduction in an electric furnace by some reducing agent other than carbon; and, third, by direct reduction with carbon in an electric furnace.

"In manufacturing ferrotungsten by the crucible process, conconcentrates are placed in a clay-lined crucible with the proper proportions of reducing agent and flux, and heated to a high temperature in a gas-fired furnace. There is considerable wear on the crucible in this method. For a 30 per cent tungsten alloy the crucible will last about three heats, but for a 65 to 75 per cent product they last but one heat. Higher percentage tungsten alloys than this are not made in the crucible furnace.

"In the electric furnace process, ferberite, wolframite, hubnerite or scheelite are reduced with carbon in an arc furnace. As with many expensive alloys, the process is generally an intermittent one, *i. e.*, the reduced charge is tapped from the furnace before another charge is added, or the charge is let solidify and chiseled out of the furnace. Sometimes a campaign of several days is made. The reduced alloy is either decarburized with refining slags in the same furnace or melted and refined later in another furnace. The furnaces used are similar in design to the ones described for ferrochrome production, but a more complete recovery is effected by the use of a tilting rather than a stationary furnace. Wolframite, feberite and scheelite are reduced easily in the electric furnace, most of the manganese being volatilized. Scheelite is more difficult to reduce, and very sticky basic slags result. There is a greater loss in its reduction, so that it does not command as high a price as the other ores, selling for about $1 per unit less. The product is tapped into molds, broken up on cooling, and packed into kegs or boxes."

The author describes some experiments made by him on the reduction of ferberite with carbon to produce ferrotungsten in the electric furnace. From the experiments the following conclusions are drawn: "First, ferrotungsten can be produced directly from ferberite in the electric furnace; second, by the use of a decarburizing slag before tapping, the percentage of carbon in the alloy can be kept below 2 per cent; third, manganese, silicon, phosphorus and sulphur do not enter the ferroalloy in high percentages; fourth, the loss of tungsten in the slag need not be excessive, and, fifth, the power consumption need not exceed 3.46 kilowatt hours per pound of ferrotungsten tapped, or 0.79 kilowatt year per ton."

In discussing **ferromolybdenum** the author gives again historical notes and theoretical considerations on the reduction of molybdenum ores. Concerning the process of manufacture the author says:

"The commercial manufacture of ferromolybdenum is carried on in an electric furnace of the electrode type operated as a resistance furnace, or in a crucible furnace of the resistance type. Comparatively little ferromolybdenum is made because of difficulty in getting ores. This is due to the fact that satisfactory methods of concentration for molybdenite ores have not been fully worked out as yet. . . .

"Buyers require an ore or concentrate containing 90 to 95 per cent molybdenite, for which the price is about $450 per short ton.

"In commercial manufacture, raw or roasted molybdenite, iron turnings, lime and coke or coal are mixed to give a ferromolybdenum of desired proportions, and treated in the electric furnace. The furnaces are operated intermittently, *i. e.*, one charge is completely discharged before another is added. Ferromolybdenum is first made as a high-carbon alloy containing 3 to 4 per cent carbon. This is then decarburized with a lime slag or a slag of lime and iron oxide. If the latter is used the percentage of iron in the alloy is increased."

From some experimental work of the author on the electric smelting of molybdenite the following conclusions are drawn: "First, that ferromolybdenum low in carbon can be made directly from molybdenite in the electric furnace, with excess lime as a desulphurizing agent and carbon as a reducing agent; second, that a product of low percentage carbon can be made, and, third, that sulphur can be readily slagged as calcium sulphide with a charge of excess lime."

The paper is concluded by some notes on **ferrovanadium.**

"Most of the ferrovanadium made is produced by the thermit process, by reduction of the oxide V_2O_5 in a crucible with carbon or by reduction of vanadate of iron with carbon in a crucible. In Europe some ferrovanadium is made by reduction of the oxide, sulphide or vanadate of iron with carbon in the electric furnace.

"The largest source of vanadium is the Peru deposit of patronite, a sulphide of vanadium containing about 60 per cent sulphur and 20 per cent vanadium. In Colorado and Utah there are large deposits of low-grade carnotite, a uranium and vanadium oxide mineral. Another ore found there is roscoelite, which contains vanadium oxide but no uranium.

"Patronite ore is first roasted and then reduced by the thermit process. Or, in the electric furnace it may be directly reduced with lime as a desulphurizing agent and carbon as a reducing agent. The other ores are treated by chemical or ore-dressing processes to obtain the vanadium as oxide or vanadate of iron, and then reduced with carbon in a combustion or electric furnace or by the thermit method. With oxide the electric furnace method is similar to the production of ferrotungsten with carbon as a reducing agent. The sulphide reduction is similar to that of molybdenite with lime and carbon. Several methods have been patented using silicon as a reducing agent in the electric furnace. The process as carried on in the electric furnace has no novel features beyond those stated regarding chromium, tungsten and molybdenum. Decarburization is with oxide of iron ore or oxide ore of vanadium. Vanadium is rather difficult to reduce, and as a result excess carbon is used, which is absorbed up to about 1 to 4 per cent."

The Carnotite Industry

A paper on this subject by Dr. **Siegfried Fischer,** Golden, Colo., is interesting in its relation to the production of radium.

Mineralogical investigations have shown two sources which contain uranium in sufficient amounts and of which there are large enough deposits to justify their commercial working. These are pitchblende and carnotite. While there are considerable deposits of monazite, the thorium mineral which also carries at times small amounts of uranium, its comparatively low radio activity eliminates it from becoming a true source for radium production.

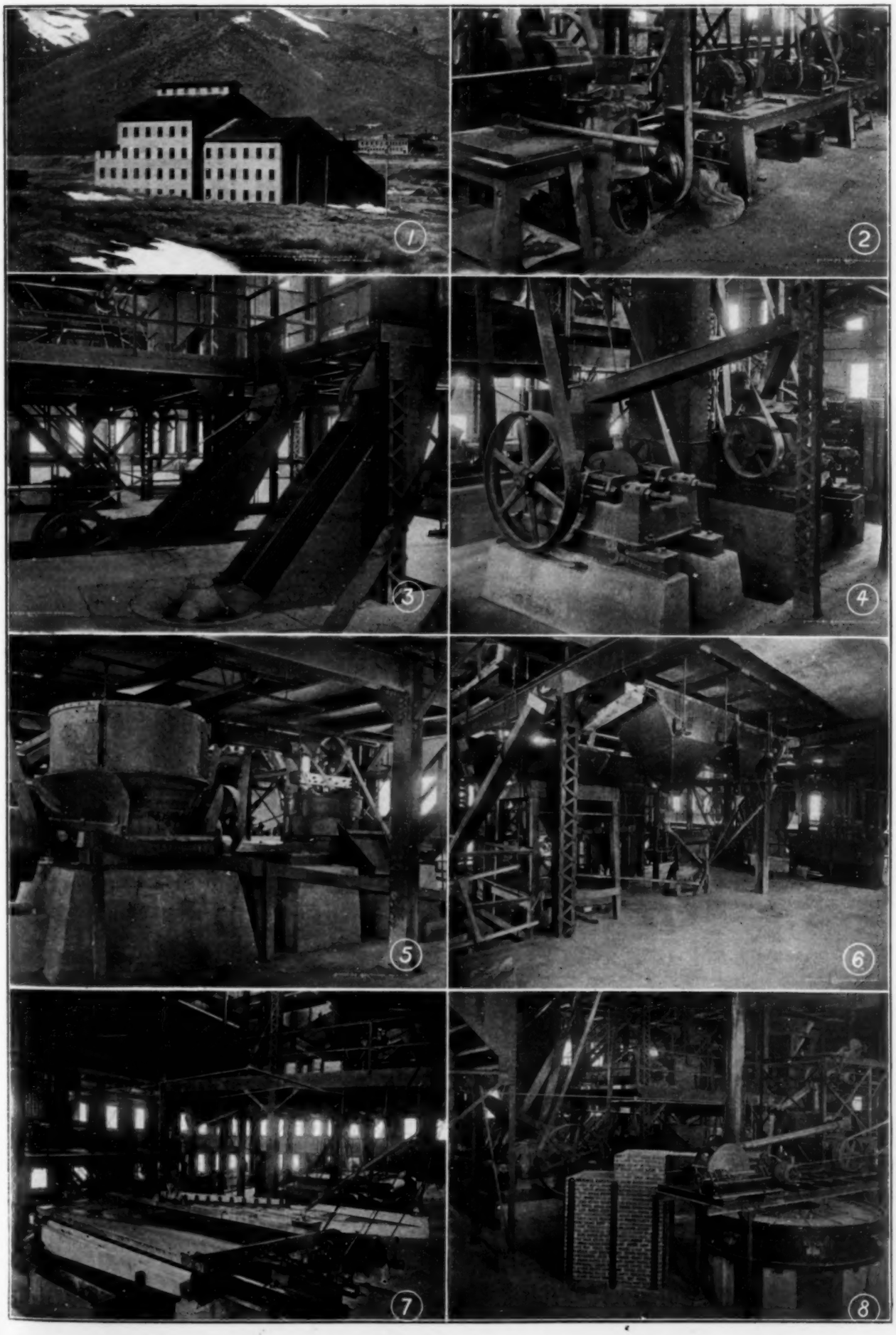
Up to recent years pitchblende was *the* commercial uranium ore.

The author's paper discusses the possibilities of carnotite for winning radium. Carnotite is a dark green to canary yellow, soft, powdery impregnation in some gangue material such as sandstone, limestone or clay, and on rare occasions in coal. According to the percentage of uranium in an ore, the yellow color and the radio-activity are more or less dominant.

Data are given on the analysis of carnotite ores, and occurrence. The main sources of carnotite are Colorado and Utah. Up to recent years nearly all the carnotite was shipped to Europe. All the radium made was a foreign product, and it was thought that America was incapable of utilizing its own crude material. "This idea is now a thing of the past, as only last month $30,000 worth of radium was shipped abroad by an American firm. It will probably not belong before this country is one of the main producers of this valuable element."

"The intrinsic value of carnotite lies in its uranium and vanadium contents, and on these factors the commercial value is based. It is rather hard to give definite figures which will hold true in all cases, as the signed contracts between the dealer and the buyer are of an extremely varied nature. The only data that I can vouch for are from a Colorado firm selling carnotite, and the figures held for last year.

"The contract stated that ores must contain at least 2 per cent U_3O_8 and a maximum of 5 per cent V_2O_5 if anything at all was paid for the vanadium. On this bases the U_3O_8 sold at $1.25 per pound, and the vanadium oxide at $0.30 per pound. For foreign shipments the cost per pound of V_2O_5 was $0.70 f. o. b. Hamburg or Liverpool. The price for the uranium to these ports is not known to me. For each



FIGS. 1 TO 10.—TESTING PLANT, COLORADO SCHOOL OF MINES. (FOR DESCRIPTION SEE PAGES 569 AND 589.)

per cent over the percentage stated in the contract the price per pound increased $0.05.

"The same firm claims that the profit per ton is $20, and the net cost per ton of ore is between $50 and $60, including sampling and analyzing.

"This crude industry is very simple. The ore is mined and sampled, analysis is made at both ends, and the product is sold on contract. But more recent researches performed in this country will undoubtedly put the carnotite industry on a more scientific and commercial foundation."

The author discusses at some length the question whether concentration is desirable or not as a first step in the treatment of carnotite. European trade seems to demand that the material be delivered without mechanical change. But the author pleads in favor of concentration and gives as his argument an abstract of his article published in this journal, June, 1912 (our Vol. 10, page 356).

As to subsequent chemical treatment the author distinguishes three steps: Extraction of values; separation of uranium and vanadium; production of radium from uranium.

As to the extraction of values (see also the author's article in our issue of August, 1912, Vol. X, page 469) there are two treatment methods in use at present—acid and basic extraction.

With respect to *acid* extraction processes information is given on the Flech, Haldane, White patents 880,645 of March 3, 1908, and 890,584 of June 9, 1908.

"The acid process has never appealed to me for the reason

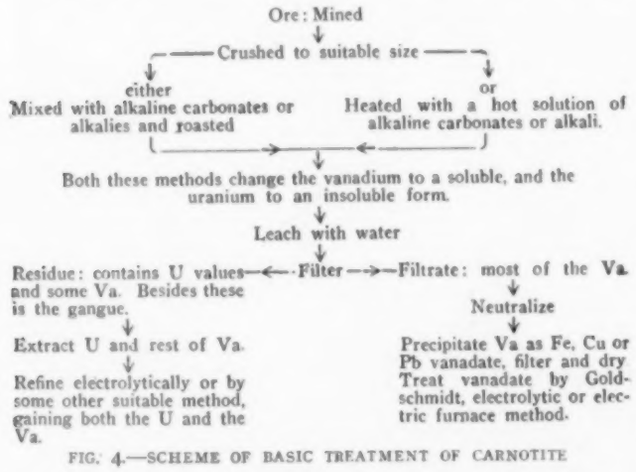

Ore: Mined
Crushed to suitable size
either
Mixed with alkaline carbonates or alkalies and roasted
or
Heated with a hot solution of alkaline carbonates or alkali.
Both these methods change the vanadium to a soluble, and the uranium to an insoluble form.
Leach with water
Residue: contains U values and some Va. Besides these is the gangue.
Filter
Filtrate: most of the Va.
Neutralize
Extract U and rest of Va.
Refine electrolytically or by some other suitable method, gaining both the U and the Va.
Precipitate Va as Fe, Cu or Pb vanadate, filter and dry Treat vanadate by Goldschmidt, electrolytic or electric furnace method.

FIG. 4.—SCHEME OF BASIC TREATMENT OF CARNOTITE

that so many impurities are brought into the extraction product, and must be gotten rid of at some stage of the operation. The patent also shows that the process is a tedious one, requiring many steps, thus increasing the time, reducing the output and increasing the cost. In spite of these facts, however, a plant is in operation based on these patents. Whether or not it is a success time alone can show, since it has been running less than a year."

A general diagram of the *basic* treatment scheme is shown in Fig. 4.

Most of the work along the line of the basic extraction of the values from carnotite was done by Warren F. Bleecker, now with the Standard Chemical Company of Pennsylvania. Bleecker's patents 1,049,330 (January 7, 1913), 1,015,469 (January 23, 1912), 1,050,796 (January 21, 1913), and Fischer's patent 1,054,102 (February 25, 1913) are outlined.

"Radium being closely allied to barium, a barium separation was performed on pitchblende ores. On this basis I have treated several uranium concentrates obtained from carnotite; and have had fairly good results. The quantity of concentrates used having been comparatively small, the barium and radium sulphate residues were not of sufficient amount to make absolute examinations on them, but the uranium residue, after treatment to eliminate all foreign matter, showed a decided decrease in radio-activity. Three methods are claimed to be applicable to carnotite for the extraction of the radium, their commercial value depending greatly on the locality in which the manufacturing of the radium salts will take place. For further knowledge on this topic we will have to await the publications of the Bureau of Mines in Denver, which is doing extensive and most valuable work in this direction.

"As no industry can be considered a success until all the by-products are utilized, the carnotite industry cannot be classed as a fully developed commercial process. Vanadium has an established market; the demand for radium is increasing steadily, but what becomes of the uranium? When we consider 2,600,000 parts by weight of uranium will produce only one part of radium, it is evident how insignificant, commercially speaking, the amount of radium is in comparison to uranium. And yet for this important by-product of the carnotite industry there is practically no market demand. Some uranium is used in the glass and porcelain industry as a color medium, but the amount is a mere bagatelle. This subject calls decidedly for research. Some of the large steel companies have tried to use uranium in their line of work, but with little or no success. This seems to have discouraged investigators, and the work spent on this element, outside of producing radium, has nearly ceased. I would like to suggest investigating alloys of uranium with other metals besides iron. It may be that it will contribute properties to some that may be of the greatest value and open up a market for what is now practically a waste product."

Base-Metal Thermocouples

A paper by Prof. **O. L. Kowalke,** of the University of Wisconsin, discusses the possibility of getting reliable base-metal thermocouples.

One of the chief causes for the inaccuracy of a thermocouple is heterogeneity of the wires.

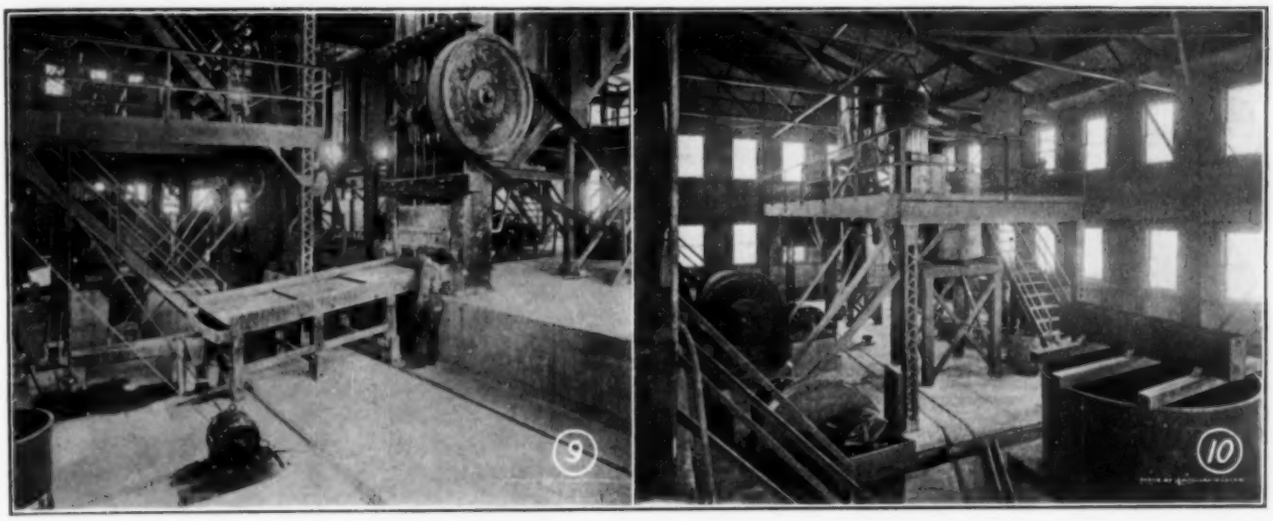
"Since the voltage generated by the couple for a given temperature is the summation of all the electromotive forces due to the contact of two dissimilar metal portions, it can readily be seen that it is imperative that the metal be as homogeneous as possible if the electromotive force indicated be that resulting from the two metals at the hot junction. If, then, the couple is composed of metal which is not homogeneous, then at each junction of two dissimilar metals there will be set up a voltage which is a function of the temperature existing at that point. Should the position of the couple be changed with respect to its depth of immersion, then the resulting voltage will be changed even though the temperature had not changed at all. A couple made of wires which are perfectly homogeneous is apt to be rather expensive, and the only combination which seems to fulfill this condition is the platinum and platinum-rhodium couple.

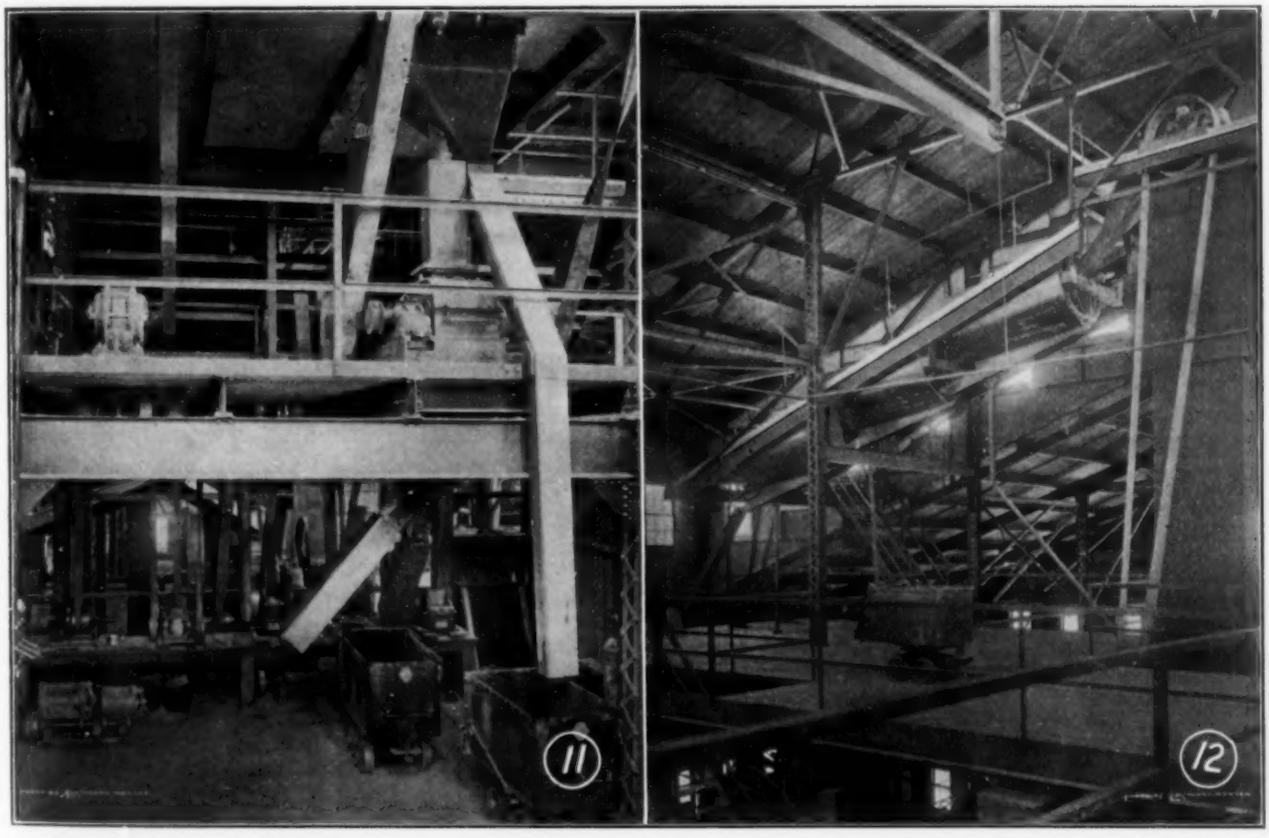
"It is possible to get a couple which is sufficiently homogeneous so that the indications are satisfactory for many commercial purposes where an accuracy of about 25 to 50 degrees is wanted. This condition is realized in the combinations of which base metal couples are made. Not all of the couples meet this condition with the same accuracy, and not all of the couples retain their original accuracy. Some couples appear to change or deteriorate with use more than others, due to oxidation, crystallization, segregation of the metal and other undetermined causes.

"It was the purpose of this investigation to determine how electromotive forces of couples varied with the temperature, and how constant this force remained with successive heatings and coolings, and also when exposed to various temperatures for extended periods of time.

"Couples were purchased from five of the prominent makers, and were cut to lengths of about 18 inches. To each couple about 3 feet of flexible lamp cord was soldered, and the wires at the point of soldering and all other required points were carefully insulated from each other."

These couples were subjected to the following careful tests: Calibration with a length of 4 inches heated; calibration with a length of 15 inches heated; heating to 400 deg. C. per 24 hours and renewed calibration with a length of 15 inches





Ore Dressing and Metallurgical Plant, Colorado School of Mines. Figs. 1 to 8 on page 587: Fig. 1, Outside View, Ore Dressing and Metallurgical Plant, Colo. School of Mines. Fig. 2, Preparation of Samples. Fig. 3, Grizzlies and Coarse Crushers. Fig. 4, Rolls and Elevator. Fig. 5, Clean and Huntington Mills. Fig. 6, Classifiers and Jigs. Fig. 7, Concentration Tables. Fig. 8, Wilfley Roaster. Fig. 9, Stamp Battery and Plates. Fig. 10, Tube Mill and Cyanide Department. Fig. 11, Sampling Apparatus. Fig. 12, Elevator and Trommels.

heated; heating to 600 deg. C. for 24 hours and renewed calibration; heating to 800 deg. C. for 24 hours and renewed calibration.

The wires of the five couples had the following composition, the negative element being given first, the positive second:

(1) Alloy of nickel and chromium, alloy of nickel and iron.

(2) Nickel with a small amount of aluminium, iron-nickel alloy.

(3) Nickel with a small amount of aluminium; iron with a small amount of nickel.

(4) Nickel with a small amount of iron; iron with a small amount of nickel.

(5) Nickel-copper alloy; iron-manganese alloy.

These couples had different protective coverings, of which one with a winding of asbestos cord, over which there was applied a solution, presumably sodium silicate, was apparently the most robust and satisfactory of the whole lot.

The results of the tests are given in form of diagrams and tables. They are thus summarized by the author:

"This series of investigations seem to point to the fact that it is possible to obtain a base-metal couple which is reasonably homogeneous and will give indications of temperature which are sufficiently constant to meet the needs of perhaps the greatest number of requirements for high-temperature measurements in the industries.

"There are some instances where the temperature is to be known to an accuracy better than 25 deg., and for such requirements it would be necessary to use a higher grade of equipment, and, furthermore, for such requirements it will be necessary to make frequent calibrations.

"It would seem reasonable that the makers of thermocouples determine from the purchaser the particular conditions under which the couple is to be used and that the calibration of this couple be made for the same length of immersion at which the purchaser is going to use it.

"A couple which will indicate an apparent difference of temperature amounting to about 130 deg. C. when immersed at different lengths in the bath or furnace is not giving the service that ought to be rendered.

"From these tests it appears that not all manufacturers are careful in sending out couples which have been thoroughly annealed to remove all strains resulting from mechanical treatment. Once the couple has attained its permanent structure there does not seem to be much change in the electromotive force."

Osmium-Platinum—A New Alloy

A brief paper by Dr. **F. Zimmermann,** of Baker & Co., Newark, N. J., gives an account of a research made to find a substitute for iridium-platinum on account of the growing scarcity of iridium.

Highly refined platinum and osmium have been successfully combined in widely varying proportions yielding alloys of commercial value. While the two metals may be combined in almost any proportion, alloys containing from 1 to 10 per cent of osmium and 99 to 90 per cent of platinum are chiefly used.

Great purity of the components is essential, as the presence of small percentages of other elements appears to be very detrimental to the properties of the resulting alloy. According to the chemical and physical behavior, it seems that one part of osmium in an alloy with platinum will take the place of two and one-half times its weight of iridium. The osmium-platinum alloy is very acid-resisting, and for this reasons may be of great service in the electrochemical industry. Its electrical resistance is considerably higher than that of an iridium-platinum alloy of the same percentage composition. The alloy further possesses great hardness and tensile strength. Wires of the finest size are drawn with comparative ease.

Effect of Light on Decomposition Voltage

The paper on this subject by **Alan Leighton,** of Cornell University, reaches the following conclusions:

The decomposition voltage of a copper sulphate solution between platinum electrodes is not affected appreciably when the anode is illuminated by a mercury vapor lamp.

The decomposition voltage of a copper sulphate solution between platinum electrodes is increased when the cathode is illuminated by a mercury vapor lamp.

The light tends to make the solution and the deposited copper less stable. The latter effect is the greater under the conditions of the experiment.

It is possible to regulate the voltage so as to make copper precipitate on the shaded portions of the platinum cathode and not on the illuminated portion.

Graphite absorbs something from a copper sulphate solution, presumably a cuprous salt, which acts as an anodic depolarizer and can be removed by electrolytic oxidation. The reaction is accelerated by light.

Owing to this absorption the decomposition voltage for a copper sulphate solution with a graphite anode and a platinum cathode can be brought down temporarily to about 0.4 volt.

Rapid Refining of Copper with a Rotating Cathode

The paper on this subject, by **C. W. Bennett** and **C. O. Brown,** of Cornell University, points out that electrolytic refining of copper, as it is ordinarily done, is carried out with a current density of from 2 to 4 amperes per square decimeter of cathode surface. The amount of copper precipitated in one or two hours by a current of this density is small unless the cathode surface be very large.

For the purpose of demonstrating electrolytic refining as a laboratory experiment, the apparatus must be small, the amount of metal deposited must be appreciable, and the time must be limited. If the cathode be rotated rapidly the current density can be increased greatly, current densities up to about 425 amperes per square decimeter having been used. With a small apparatus using current densities of this magnitude, sufficient amounts of copper for demonstration purposes can be deposited in a short time and appreciable amounts of the impurities may also be obtained as slimes.

The authors describe some tests on the rapid refining of copper to show that it could be done, and also with the idea of using it as a laboratory experiment. The experiments serve only to show that the same conditions obtain in rapid refining as in the commercial refining. They also give another instance of the rapidity of electrochemical work when the solution is stirred vigorously.

The experimental arrangement is described and illustrated.

The tests were made with a copper anode containing silver as only impurity, with an anode containing silver, arsenic and bismuth as impurities, and finally with an anode containing the usual impurities of copper anodes.

The tests show that electrolytic copper refining can be demonstrated in the course of an hour if a rotating cathode be used. The anodes may contain impurities usually found in commercial anodes, the demonstration being more striking if the impurities are present in amount approximating 1 per cent each. The anodes should be contained in a diaphragm, and the slimes may be removed partially with the diaphragm and the remainder by means of a stiff brush and water from a wash bottle. The deposited copper may be stripped off and sampled if aluminum cathodes are used.

Arsenic shows the largest tendency to contaminate the refined copper. It requires, however, the delicate Marsh test to detect this metal.

The statement that silver dissolves in neutral copper sulphate solution is probably an error.

Simultaneous Determination of Copper and Lead with the Rotating Anode

A paper by **Arthur J. White,** of Philadelphia, Pa., points out that, in electrolyzing nitric acid solutions of copper, lead tends to hold up some of the copper. However, an addition of sulphuric acid allows of copper being completely precipitated from a nitric acid solution while lead is being determined simultaneously on the anode, provided that the proportion of lead is not high enough to precipitate lead sulphate. This salt does not appear unless the proportion of lead to copper is greater than one to four, as the copper nitrate exerts a solvent action on smaller quantities.

When less than 0.15 gram of lead is present with 0.60 gram of copper, they are quantitatively precipitated in thirty minutes by a current of 8 amp at 6 volts.

The best proportions of acid are 4 cc. concentrated nitric acid and 10 drops of concentrated sulphuric acid in a volume of 70 to 80 cc. The anode is rotated at from 400 to 700 revolutions per minute and the copper is deposited on a 60-gram platinum dish.

The application to brass analysis is described in detail and some further observations are given which seem to warrant the application of the method to other alloys, provided they contain less than 2 per cent of arsenic or bismuth. These metals in small quantities act as reducing agents and require the addition of a little more nitric acid, whereas iron has an oxidizing effect and allows of less nitric acid being used.

Solid Thick Deposits of Lead from Lead Acetate Solution

The paper on this subject, by Prof. **Frank C. Mathers,** of Indiana University, emphasizes that "any soluble lead salt will give a solid, dense, coherent electrolytic deposit if the proper addition agents are used. Those solutions which do not give good deposits will do so when the proper addition agents are introduced. This theory cannot as yet be proved in all cases, but this paper gives the experimental proof in the case of lead acetate solutions."

Peptone was found to be the best addition substance for use in lead acetate solutions containing ammonium perchlorate. The effect of varying amounts of ammonium perchlorate, the effect of acetic acid, the effect of the quantity of peptone and of other factors were studied in detail.

Of other salts in place of ammonium perchlorate, sodium perchlorate and sodium naphthalene sulphonate gave good deposits.

Among other addition agents the following were studied: Extract from feathers, casein boiled in acetic acid, casein modified by digestion with enzymes, tannin, meat extracts, vegetable extracts, essential and fatty oils, gums.

* * *

After a vote of thanks to all who had made this Colorado meeting so eminently successful, the meeting adjourned.

The final meeting held on top of Pike's Peak has been reported above.

The next meeting will be held in April, 1914, in New York City.

The following is a complete alphabetical list of those who registered at the meeting:

John C. Bailar, Golden, Colo.; T. F. Bailey, Alliance, Ohio; F. S. Bauer, Boulder, Colo.; E. A. Beck, New York City; F. D. Burr, Denver, Colo.; W. W. Case, Jr., Denver, Colo.; Regis Chauvenet, Denver, Colo; W. R. Chedsey, Golden, Colo.; G. B. Chorpening, Clarksburg, W. Va.; F. L. Clerc, Boulder, Colo.; G. H. Clevenger, Palo Alto, Cal; C. L. Colburn, Butte, Mont.; A. E. Gerald Collins, Denver, Colo.; Mr. and Mrs. C. E. Collins, Denver, Colo.; C. W. Comstock, Denver, Colo.; W. D. Coolidge, Schenectady, N. Y.; E. L. Crosby, Detroit, Mich.; C. L. Devine, Clarksburgh, W. Va.; D. C. Dodge, Denver, Colo.; Mr. and Mrs. J. V. N. Dorr, Denver, Colo.; C. J. Downey, Denver, Colo.; Wm. Dreyfuss, New York City; Mr. and Mrs. H. C. Eastman, Denver, Colo.; J. B. Ekeley, Boulder, Colo.; E. J. Ericson, St. Louis, Mo.; H. S. Evans, Boulder, Colo.; C. G. Fink, East Orange, N. J.; Herman Fleck, Golden, Colo.; Prof. and Mrs. F. C. Frary, Minneapolis, Minn.; R. H. Gaines, New York City; A. Galbraith, Chicago, Ill.; A. E. Gibbs, Philadelphia, Pa.; F. W. Gill, Arlington, N. J.; Prof. and Mrs. S. L. Goodale, Pittsburgh, Pa.; J. R. Griffiths, Niagara Falls, N. Y.; H. M. Hall, Massena, N. Y.; C. A. Hansen, Schenectady, N. Y.; R. S. Hawley, Golden, Colo.; C. W. Henderson, Denver, Colo.; C. B. Hersey, Denver, Colo.; A. T. Hinckley, Niagara Falls, N. Y.; M. B. Holt, Denver, Colo.; A. J. Hoskins, Denver, Colo.; Mr. and Mrs. Wm. Hoskins, Chicago, Ill.; Miss Hoskins, Chicago, Ill.; J. A. Hunter, Boulder, Colo.; B. H. Jackson, Boulder, Colo.; D. R. Jenkins, Boulder, Colo.; H. W. Kellogg, Niagara Falls, N. Y.; Prof. and Mrs. Geo. Kemmerer, Socorro, N. Mex.; S. P. Kinney, Salt Lake City, Utah; K. A. Kithil, Denver, Colo.; R. Lachman, Breslau, Germany; F. B. Laney, Washington, D. C.; L. R. Leonard, Boulder, Colo.; O. C. Lester, Boulder, Colo.; F. A. Lidbury, Niagara Falls, N. Y.; S. C. Lind, Denver, Colo.; H. B. Lowden, Denver, Colo.; D. H. Lyon, Pittsburgh, Pa.; J. A. MacDonald, Denver, Colo.; P. S. MacGregor, Boston, Mass.; J. L. Malm, Denver, Colo.; B. S. Manuel, Denver, Colo.; J. A. Mathews, Syracuse, N. Y.; M. S. McCarthy, Denver, Colo.; A. McK. Gifford, Pittsfield, Mass.; R. McNeill, New York City; L. F. Miller, Golden, Colo.; R. B. Moore, Denver, Colo.; J. M. Muir, New York City; Mr. and Mrs. H. C. Parmelee, Denver, Colo.; O. C. Ralston, Colorado Springs, Colo.; J. W. Richards, South Bethlehem, Pa.; E. F. Roeber, New York City; J. W. Root, Denver, Colo.; C. C. Saunders, New York City; G. H. Sethman, Denver, Colo.; C. G. Schluederberg, Pittsburgh, Pa.; Prof. and Mrs. Herman Schlundt, Columbia, Mo.; Prof. and Mrs. E. P. Schoch, Austin, Tex.; Harry M. Showman, Golden, Colo.; Mr. and Mrs. L. B. Skinner, Denver, Colo.; F. W. Skirrow, Westminster, Colo.; Acheson Smith, Niagara Falls, N. Y.; W. M. Snow, Peru, Ill.; H. N. Spicer, Denver, Colo.; C. D. Test, Golden, Colo.; F. W. Traphagen, Golden, Colo.; L. D. Vorce, Detroit, Mich.; H. V. Welch, San Francisco, Cal.; E. S. Wiard, Denver, Colo.; H. J. Wichmann, Denver, Colo.; M. W. Wilkinson, Denver, Colo.; H. H. Willard, Ann Arbor, Mich.; Miss C. Wilson, New York City; L. H. Wilson, Newark, N. J.; Harry J. Wolf, Golden, Colo.

Old Freibergers in America

The dinner in honor of Oberbergrat Dr. Richard Beck, Rektor of the Freiberg Bergakdemie, Freiberg, Saxony, Germany, was held on Tuesday, September 9, 1913, at the Engineers' Club, in New York City. Many reminiscences told of former Freiberg days and several toasts were given. Mr. Franklin B. Guiterman, executive director of the American Smelting & Refining Company, acted as toastmaster. Dr. R. W. Raymond, Secretary Emeritus of the American Institute of Mining Engineers, responded to the toast "Reminiscences," Mr. Charles L. Bryden, head of the school of Metal Mining and Metallurgy, Scranton, Pa., responded to the toast "Old Freibergers in America," and Dr. Beck responded to "Alma Mater."

Dr. Beck, who has been visiting this country, attended the International Geological Congress in Canada. While there he was honored by the degree of LL.D. from the University of Toronto, Toronto, Ontario, Canada. Dr. Beck sailed for Europe on September 12.

The organization of the Old Freibergers in America is just one year old and the membership is over 60.

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Slime Agitation.—A new type of slime agitator is described in the monthly *Journal* of the Chamber of Mines of Western Australia, by Mr. H. B. WRIGHT. The device, which is illustrated in Fig. 1, is in use at the Great Boulder Perseverance mine, and has given improved results in extraction as compared with the ordinary type of mechanical agitator. It is known as the Wright-Jaentsch centrifugal aerator, and consists essentially in several pipes, say four, supported at an angle of 45 deg. in the tank and attached to the central revolving shaft. The pipes act as centrifugal pumps. Four pipes of 6 in. diameter, revolving at a rate which gives the outside ends a circumferential speed of 350 ft. per minute, have given good results. The author gives figures showing

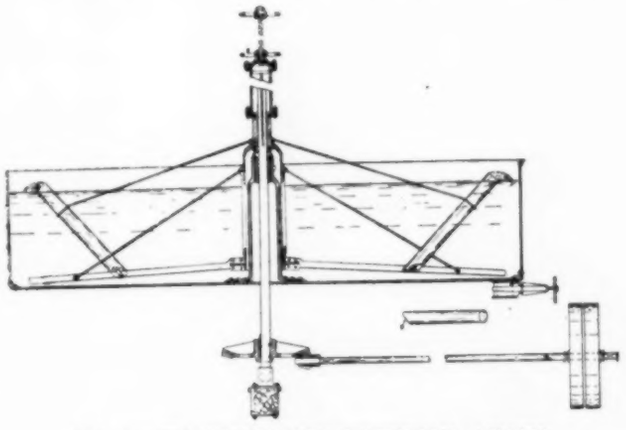


FIG. 1.—WRIGHT-JAENTSCH CENTRIFUGAL AERATOR

comparative tests between the centrifugal aerator and the ordinary mechanical agitator, working on the same pulp. The centrifugal aerator showed an increase of 7.5 per cent dissolved gold as compared with the mechanical agitator. Twenty-three of these aerators are in operation at the Great Boulder Perseverance; each vat is 20 ft. diameter and 4 ft. 6 in. deep, and the arms are rotated at 6.7 revolutions per minute. Three horsepower is required for each vat. The centrifugal force exerted is 6.5 lb. The greatest pumping effect is obtained when the pipes are just submerged, as then there is no hydrostatic head to be overcome.

The Cam & Motor Mill, Rhodesia.—One of the newest mills to be designed for the Hartley mining district of southern Rhodesia is the Cam & Motor. The method of treatment to be adopted was determined by laboratory tests supplemented by work in an experimental unit. The details of this work and an outline of the new mill are given by Mr. GORDON F. DICKSON in the August, 1913, *Mining Magazine*.

The ore has the following composition:

Silica	44.33	per cent
Iron pyrite	2.95	" "
Mispickel	2.15	" "
Stibnite	0.15	" "
Calcium carbonate	14.10	" "
Magnesium carbonate	26.10	" "
Graphite	Trace	

Laboratory experiments proved conclusively that an attempt to cyanide the raw ore would be unsuccessful, owing chiefly to the consumption of cyanide and the loss of free alkali through the decomposition of the existing minerals. Preliminary roasting indicated a high percentage extraction. A "sweet" roast was obtained in 45 minutes, and the extraction by leaching or agitation was 85 per cent to 86 per cent. The addition of both stibnite and graphite above the usual quantity was without appreciable effect, but care was required in the roasting operation to avoid fusing the stibnite. The carbonates of calcium

and magnesium were found to have a useful effect in maintaining the protective alkalinity of the solution. The dissolution of gold was rapid, and the consumption of cyanide was low.

In the operation of the experimental unit, all the data from laboratory tests were confirmed. On one occasion the extraction dropped suddenly from 85 per cent to 78 per cent, which was found to be due to the tendency of the ore to ball and sinter at the discharge of the furnace. This was remedied by lowering the temperature of the finishing hearth and opening side and end ports, whereupon the extraction rose again. Tests were made on the furnace, which is of the Edwards type, to see whether wood or coal was best for fuel. Under the economic conditions existing at the time, wood fuel proved economical. The furnaces have been constructed to burn wood, but can be changed to the coal-burning type when cheaper coal is available. One of the furnaces has been equipped with the Parkison patent fire-box of the type used at the Golden Cycle mill, Colorado Springs, Colo. This is designed to burn the coal on the producer principle and give a long incandescent flame.

Experiment has shown that 40-mesh is the economic limit of grinding. The sand and slime will be separated and treated by leaching and agitation, respectively. Caldecott cones and sand dewatering tables will be used to prepare the sand for leaching. The slime will be filtered in a vacuum filter of the fixed submerged leaf type. The entire plant will have a capacity of 15,000 tons per month.

Economics of Milling.—In the *Mining Magazine*, August, 1913, appears an article on this subject by Mr. Gelasio Caetani, being one of a series of lectures delivered by him recently at Harvard University. In our issue for August, 1913, page 464, we published an abstract of the first of this series of lectures, on the principles of mill design.

Mr. Caetani first calls attention to the fact that the object of ore treatment is not to attain the highest metallurgical efficiency, and that high percentage of recovery is not necessarily an index to the efficiency of a metallurgical plant. Metallurgical recovery and economic recovery of metals are not of equal importance; the latter is paramount in practice, being the sole object of the plant. Economic efficiency is the resultant of several factors, chief among which are (1) metallurgical efficiency, (2) freight and transport charges, (3) smelter schedule, and (4) operating cost.

Economic efficiency and metallurgical efficiency may become almost identical when the final mill products are metallic, as for instance in the case of the production of gold and silver bullion from cyanide mills, or the output of metallic copper from mills in the Lake Superior region. But there are exceptions even in such cases. The author cites an example of a cyanide mill treating a gold-silver ore, the gold content of which is recovered quite readily, whereas the dissolution of the silver is slower and requires days of treatment to reduce the tailing to its minimum silver content. In such a case the economic efficiency and metallurgical efficiency will not be identical, and it may prove more profitable to leave the silver in the ore rather than spend additional time and money in extracting it.

The discrepancy between economical and metallurgical recoveries is most apparent in concentrating mills. It hinges on the fact that, under normal operating conditions, metallurgical recovery can be increased only by lowering the grade of the concentrates, and the grade of the concentrates can be raised only at the expense of metallurgical recovery. In order to operate the mill to the best economic advantage, the metal market, smelter schedule, etc., must be taken into consideration, in order that the greatest net profit may be obtained from the mill products. Discrimination between concentrate and tailing may be dependent entirely on the intrinsic value of the material itself.

In another case, the addition of low-grade middling to the concentrate will lower the average grade to a point where the unit prices paid for the metals are also reduced thereby, entailing heavy loss. As an example, assume an auriferous pyrite in quartz, the average concentrate from which will assay 2 oz. gold and 5.4 per cent lead. Suppose the smelter contract offers $19 per oz. for gold; no payment for lead under 5 per cent, and 4oc. per unit for contents above 5 per cent; treatment charge, $5 per ton. In milling the ore we may get a middling containing gold to the value of $6.65, 2.5 per cent of lead and 16 per cent zinc. At first sight it might appear that, since the middling contains $6.65 in gold and the treatment charge is only $5 per ton, there should be a net profit of $1.65. But if 1 ton of the middling is added to 9 tons of concentrate, we will have an average grade of 1.83 oz. gold and 4.96 per cent lead. Consequently the value of the lead is entirely lost, with the result of a net loss per ton of concentrate. Mill operators sometimes delude themselves in the matter of shipping low-grade ore and mill products, and resort to the device of mixing them with higher grade material, not realizing that they are losing just as much as though the two products were shipped separately.

On the other hand, conditions may exist under which low-grade material can be thrown into the concentrate. The author cites an experience in which he disposed of the last spigot-discharge of a spitzkasten by mixing it with the slime concentrate. The profit of concentrating this spigot-discharge would have been but $1.32 per ton of dry material treated, whereas, by mixing it with the slime concentrate and shipping to the smelter it netted $4.69 per ton. The reason for mixing the two products was that the smelter would have refused to accept the low-grade spigot-discharge if shipped alone. Other instances of mixing concentrates to advantage may occur when the effect of mixing is to reduce the average grade of a deleterious constituent, such as zinc, without impairing seriously the grade of the valuable minerals. In this way a penalty on zinc may sometimes be avoided.

The author cites the operations of the Utah Copper Company as an example of the effect of large-scale operations on low-grade material. Success with a low-grade ore will depend on three factors: capacity, full load and continuity of operations.

In the case of combined concentrating and cyaniding plants, the two departments must be operated in such a way that the highest economic efficiency can be obtained. This will depend on the nature of the ore, the effect of the sulphides on the cyanide solution, the freight and treatment charges on concentrates, etc. Under some conditions it may pay to cyanide con centrates separately, and not ship them to the smelter. As an example, the practice at the Alaska-Treadwell is cited, where formerly it cost $12 per ton to ship and smelt concentrates, as against a total cost of about $5 for cyaniding at the mill.

These various considerations all emphasize the fact that the maximum economic efficiency and not maximum metallurgical efficiency is the ultimate object of the reduction plant. Many factors enter into the problem and it is the duty of the metallurgical engineer to watch the ever-changing conditions and to operate his mill in accordance with good business principles.

Zinc and Lead

Selective Flotation.—One of the recognized problems in slime concentration at Broken Hill, Australia, is the separation of galena from blende. **Mr. J. Malcolm Newman**, writing in the *Australian Mining Standard*, June 26, 1913, states that while it has been possible by flotation to recover lead, zinc and silver from the slimes, leaving a worthless gangue, it has been practically impossible to separate the two minerals into marketable products. Hitherto the separation has been attempted on concentrating tables and vanners, but the operation was unsatisfactory, even though the products could be mixed with those of higher grade and thus sold.

Recently efforts have been made to evolve "selective" or "preferential" flotation processes, whereby the galena and blende would be acted upon differently and thus yield separate concentrates. The Zinc Corporation is experimenting with two such processes, the Horwood and the Lyster. The importance of slime concentrating and separating processes is increasing with the deeper operation of the mines, for the minerals be-

come more intimately associated, and the opportunity for jigging and other forms of coarse concentrating is decreased. In fact there is already a diminution in the amount of jigging now done, and finer grinding becomes necessary to liberate the mineral particles. This produces more slime and increases loss of mineral; hence the need for methods of slime separation.

The Horwood process is better known than the Lyster. In the *Mining and Engineering Review*, Australia, July 5, 1913, some details are given of the operation of this process at the Zinc Corporation. The material treated is slime from the reconcentration section of the Minerals Separation flotation mill. It contains about 36 per cent zinc, 15 per cent lead and 22 oz. silver per ton. The slime is first thickened, then filter-pressed and dried with compressed air so that the cakes crumble when dropped from the press. The product is then roasted in an Edwards duplex furnace, at a temperature of 300 to 350 deg. The lead is sulphatized, but the zinc is unaffected, and in the subsequent flotation process only the latter floats. About 35 lb. acid and 2 to 3 lb. oleic acid are added per ton of slime. The mixture passes through seven flotation boxes, six of which produce zinc concentrate which is retreated in the seventh. The lead remains in the underflow. By this method it has been possible to produce lead concentrate containing 38 per cent lead, 8 per cent zinc and 42 oz. silver per ton; while the zinc concentrate runs as high as 50 per cent zinc, 7 per cent lead and 15 oz. silver per ton.

Less complete detail is given on the Lyster process, in the June 5 issue of the same journal. Current slime is first thickened and then fed to a centrifugal pump which is throttled to cause a violent agitation of the slime with oil and air which are admitted into the suction pipe by a small duct. The mixture is pumped to a spitzkasten with contracted overflow, in which the galena particles collect in a froth that overflows. The underflow, containing mainly zinc mineral, is then similarly treated in a second centrifugal pump with a further addition of oil, whereupon a zinc concentrate is obtained. Similar results have been obtained in Minerals Separation boxes, but the centrifugal pump is considered more efficient. The main point in the treatment seems to be successive additions of small quantities of oil followed by agitation, thus producing a fractional flotation of the different minerals. The report states that 55 per cent to 60 per cent lead concentrates have been obtained, and that a pure zinc concentrate has been made, thus demonstrating that the differential process can be applied to mixed slimes.

Tin

Electric Smelting.—Interesting details of experiments in smelting tin ore in the electric furnace are given by "A Special Correspondent" in the *South African Mining Journal* for June 7 and 14, 1913. After reviewing the present status of tin smelting in reverberatory furnaces, the author takes up theoretical considerations in electric smelting, and then cites results of experimental work. He concludes that under favorable conditions for power, the electric furnace process offers material advantages over reverberatory smelting.

The reduction of tin oxide by carbon may be assumed to occur according to the following two equations:

$$SnO_2 + C = Sn + CO_2 \quad (1)$$

$$SnO_2 + 2C = Sn + 2CO \quad (2)$$

That part of the reaction takes place according to the second equation is indicated by the fact that CO can be seen burning at the mouth of the furnace. The author assumes that reduction takes place by both reactions, probably in equal proportions.

The combustion of 118 grams, or one gram-molecule, of tin into tin oxide will yield 145,300 grams-calories of heat, which is the amount of energy required for liberating 118 grams of tin. The combustion of 12 grams of carbon into CO_2 will yield 96,960 gram-calories; and the combustion of 24 grams of carbon into CO will give 58,000 gram-calories.

If the reduction occurs according to reaction (1) the energy requirement per ton of tin will be 145,300 — 96,960 = 48,340 kg. calories per 118 grams tin, or 409,661 kg. calories per kg. tin, or 474 kw-hours per ton of tin.

In the same way the requirement according to equation (2) will be 855 kw-hours per ton of tin. Assuming that the reduction occurs to the extent of 50 per cent. of each reaction, the requirement would be, in round numbers, 665 kw-hours per ton of tin. In addition to this, a certain amount would be needed to heat the charge to the temperature of reaction.

Assuming that the ore contains 90 per cent tin oxide, we require 1280 kg. ore for each ton of tin. Experience has shown that the slag will amount to 16 per cent to 20 per cent per ton of ore, or say 220 kg. slag. The melting of a ton of slag requires, on an average, 500,000 gram-calories, or 130 kw-hours for each ton of tin. The heat capacity of the charge and molten tin may be set down as 65 kw-hours. Radiation losses are not definitely known, but are assumed to be as great as that consumed by the slag, or 130 kw-hours. The gases escaping from the furnace have a temperature of about 800 deg. C., and the loss from this source may be set down as 150 kw-hours per ton of tin. In summing up these items it appears that it should be possible to produce a ton of tin with the following expenditure of power: For the reaction, 665 kw-hours; slag loss, 130; specific heat of the charge, 65; radiation loss, 130; loss in gases, 150; total, 1140 kw-hours.

Current for the experiments under review was obtained from a Diesel engine plant, and was three-phase, 50 cycles, 650-675 volts. An oil-cooled transformer received current at 660 volts, and had four tappings capable of giving 30, 40, 50 or 60 volts of 2500 ampere current.

The furnace was a shaft of special design, which is not described owing to pending patent applications. There were three carbon electrodes, 4 in. square and 4 ft. 6 in. long, cooled by water jackets, and suspended in such a manner as to permit fine adjustment. No direct arc was permitted to be formed, as this caused a great variation in the yield and in the working of the furnace. The charge formed a cone-shaped mass on the hearth, covering the reacting zone forming a small space filled with incandescent gas in which the reaction took place. Arrangement was made to prevent the escape of volatile metal, and only about 0.5 per cent of metal was thus lost.

At the start of a campaign of ten or twelve days, the furnace was preheated by a wood and coke fire. The charge contained 14 kg. culm for each 100 kg. ore. Current was first used at 60 volts, 1000 amperes per phase, and as the reaction proceeded this was changed to 40 volts and 2500 amperes, which current was maintained during the smelt. Metal was tapped half an hour after charging, and slag was drawn after the furnace had been running two hours. The proper operation of the furnace could be judged by the appearance of the slag; if it flowed freely, and was a dark brownish green color, the charge was right, but if the slag appeared sluggish and light brown a change was indicated.

Metal from the tap-hole assayed 98 per cent pure. In one case Bolivian ore of 49.9 per cent tin and 15 per cent iron was smelted for 10 days, with a net recovery of 92 per cent, running as high as 97 per cent recovery on one day. The grade of the metal from the furnace was raised to 99.75 per cent pure by simply blowing air through it.

The output, power consumption and loss in slag were found to be in close relation. It was possible to produce slag containing only 0.25 per cent metal, but this was not economical at the price for power. The output was only 6 to 8 cwt. per day, and the power consumption was 3000 kw-hours per ton of metal. On the other hand a slag containing 17 per cent to 18 per cent tin was produced, the output of metal being 1 ton and 11 cwt. per day, with a power consumption of only 1300 kw-hours per ton of metal. This slag would have to be retreated.

It was finally found most economical under prevailing power

conditions to obtain a recovery of 96 per cent to 98 per cent, with a high power consumption.

The following figures refer to operations during the week of July 28 to Aug. 4:

Ore smelted—		
20,056 lb., 57 per cent tin	12,003 lb.	metal
Scrap and refuse	2,324 "	"
Tin produced	14,170 "	"
Net yield	98.75%	
Electrode consumption, per ton tin	28 lb.	
Power consumption per ton tin	1,800 kw-hours	

An Electrolytic Refinery in Wall Street

The Assay Office of New York

It has been said by a cynic that the only chemical compound with which modern financiers are thoroughly acquainted is water and that more than one triumph of modern industry has been acquired by utilizing the reaction between stock and water. Be that as it may. It is a plain fact that there is a real electrolytic refinery in Wall Street, New York City, small in size, it is true, but very big in the value of its output. This is the United States Assay Office. Next to it is the Sub-Treasury, and across the street is the office of J. P. Morgan & Company. No explanation is necessary to show that this electrolytic gold and silver refinery is at its logical place.

The relation between the Assay Office and the public is

FIG. 1.—ANODE MELTING FURNACES

twofold. First, the Assay Office buys impure gold and gold-silver alloys from the public. This may be the gold output of a copper refinery or of a cyanide mill or gold scrap from dentists, or gold imported from Europe, or old jewelry. Second, the Assay Office refines this gold and alloys for the various requirements of the public.

The metallurgical process carried out at the Assay office is, therefore, the separation of the gold from the silver and the other metal impurities and the production of the pure metals.

Formerly the sulphuric acid parting process was employed, but the electrolytic refining process has now been universally introduced into the United States Mints, and when a few years ago the New York Assay Office was damaged by fire and it became necessary to rebuild and reequip the Office thoroughly, it was decided to introduce electrolytic refining.

There is no necessity here to enter into all the intricacies of the electrolytic refining of gold and silver, since they have been dealt with in detail in numerous articles in this journal, written by the highest authorities. Reference to these articles must therefore suffice. The most important are by the inventor of the electrolytic gold refining process, Dr. E. Wohlwill, in our vol. II, p. 221 and 261, and vol. VI, p. 450; by Dr. D. K. Tuttle, who introduced the process in the Philadelphia mint and worked out a method of treating gold-silver alloys high in silver, vol I, p. 157, and vol. IV, p. 306; an article on the use of pulsating current in the Wohlwill gold refining process, vol. VIII, p. 82; further see the articles by Whitehead on the refining process in use at the San Francisco mint, vol. VI, p. 355 and 408 and by Dr. E. F. Kern, vol. IX., p. 443.

In buying gold or gold alloys from the public, the Assay Office has fixed only two restrictions. These are that the ma-

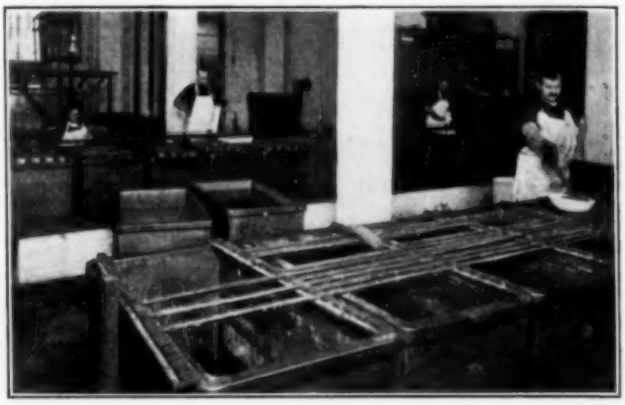


FIG. 2.—ELECTROLYTIC SILVER CELLS

terial shall contain not less than 20 per cent. of gold and silver and shall be worth at least $100. The purchased deposits are melted down and molten dip samples are taken for assays.

Now a separation is made according to whether the per-

FIG. 3.—ELECTROLYTIC GOLD CELLS

centage of gold is less than 90% or more than 90%. In the first case the material goes to the silver refining room, in the latter case directly to the gold refining room.

FIG. 4.—GENERAL VIEW, DEPOSIT MELTING ROOM

The crucible furnaces employed for melting the material and casting into anodes for electrolytic silver refining are shown in Fig. 1, the electrolytic silver refining room in Fig. 2. The electrolyte is a solution of 3 percent nitrate of silver and 2 percent free nitric acid, this composition being carefully maintained. The tanks are of brown stoneware.

The anodes contain from 250 to 400 parts of gold, 150 or less of base metals, and the remainder silver (out of a total of

1,000 parts). The anodes are contained in muslin bags to retain the slime. The solution is stirred by a small belt-driven glass propeller in each tank.

The silver and base metals are dissolved in the electrolyte,

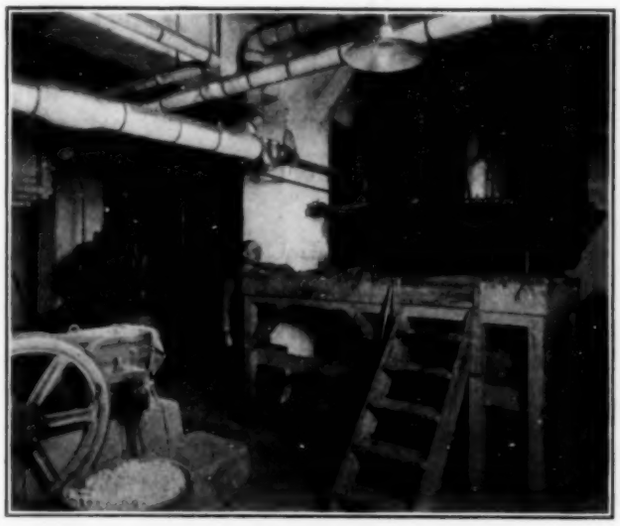


FIG. 5.—SWEEP HANDLING MACHINERY

but the silver alone is deposited on the cathode. The gold remains in form of slime in the anode bags. Every eight hours each cathode is lifted and the silver deposit is scraped off.

The current density is seven amperes per square foot.

The solution is frequently renewed. The gold content in the cathode silver is carefully watched and not permitted to exceed 2 parts in 100,000.

The gold refining room is shown in Fig. 3. Here the Wohlwill process is used. The cells are of Royal Berlin porcelain. The electrolyte is a gold chloride solution with some free hydrochloric acid. Pulsating current is used. The current density is 70 effective amperes per square foot.

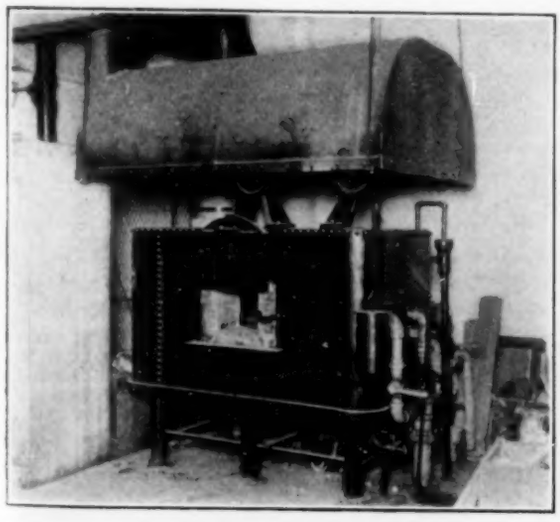


FIG. 6.—REVERBERATORY MELTING FURNACE

The platinum and palladium recovered in this process are sold to the highest bidder.

Both gas and oil are used for melting purposes in the New York Assay Office, as a matter of precaution, to make continuous operation absolutely sure. The whole furnace equipment of the Assay Office has been supplied by the W. S. Rockwell Company of New York City, who designed several special furnaces for the special requirements of the Office.

Fig. 4 shows the room for the melting of the gold in crucible furnaces, Fig. 6 a reverberatory furnace, for special uses, like the cupelling of base bullion which contains too much base metals to permit the application of the ordinary refining process.

Fig. 7 shows the testing laboratory where the different

FIG. 7.—TESTING LABORATORY

solutions are tested; Fig. 8, the office of the melting and refining department and the make-up room.

Fig 5 shows the sweeps department which has recently been installed in the basement. The equipment consists of a jaw crusher which crushes the sweeps to one-half inch or less in

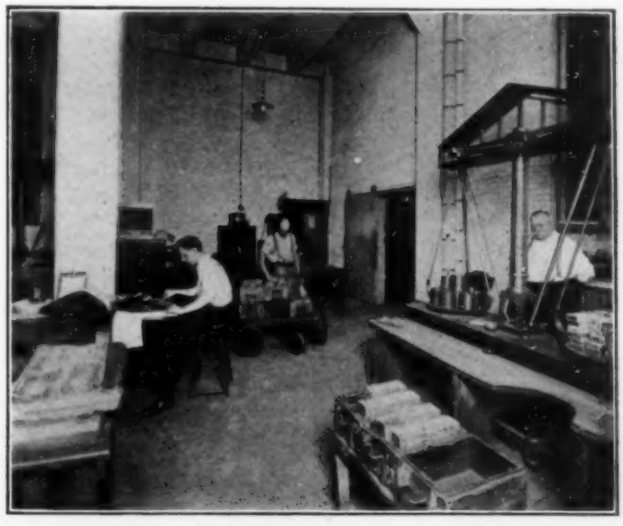


FIG. 8.—OFFICE OF THE MELTING AND REFINING DEPARTMENT AND MAKE-UP ROOM

diameter, a grinding mill of the Chilean mill type, which grinds the sweeps under water so as to pass a 60-mesh screen to two settling tanks, and a steam dryer.

Homogeneous Lead-Lining and Lead-Nickel-Lining.—We have received an interesting illustrated circular on this subject from Mr. Bartholomew Viola, 140 Liberty Street, New York, the American representative of Kühnle, Kopp & Kausch. The "homogeneous lead-lining" is recommended particularly for vacuum appliances, for cookers, and for all lead-lined vessels, working under pressure. The lining is claimed to be so intimately adhering that the two metals are inseparable. Another interesting novelty of this firm are wrought iron and copper vessels with a lead-nickel lining, as a substitute for pure nickel vessels. The joining layer of lead is stated to combine the metals so intimately that they cannot become loose by heat or high pressure. The nickel coating is only a few millimeters thick so that the cost is not excessive.

A New High-Resistance Thermo-Electric Pyrometer

In the deservedly widespread use of the thermo-electric pyrometer the desirability of having the resistance of the millivoltmeter comparatively high has long been recognized, but there have been difficulties in producing such an instrument at a comparatively low cost.

For this reason low-resistance thermo-electric pyrometers have been very generally used, the resistance of the millivoltmeters varying between 2 to 5 ohms. With this type of instrument it is absolutely essential that the instrument be calibrated, together with the leads or connecting wires which

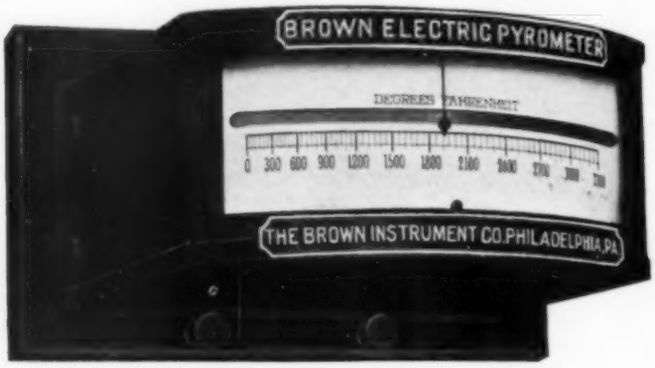


FIG. 1.—HIGH-RESISTANCE THERMO-ELECTRIC PYROMETER—INDICATING TYPE

are to be used, since any change in the length of these leads or any change in the length of the thermocouple furnished with the instrument will alter the true indication of the pyrometer so that serious errors will result. A change in the length of leads of 1 to 50 ft. is sufficient to make the average low-resistance pyrometer read 25° or more low and a change in the length of the thermocouple from 3 ft. to 4 ft. will make the same instrument read 20° more in error. For fairly accurate results, therefore, it is necessary to use the thermocouple and leads which are furnished with the instrument, or exact duplicates thereof—as long as a low-resistance millivoltmeter is employed.

It is true that for some time high-resistance galvanometers or millivoltmeters, portable in form, but not of the switchboard or wall pattern, have been produced abroad. They are, however, usually of the suspension type; that is, the moving element

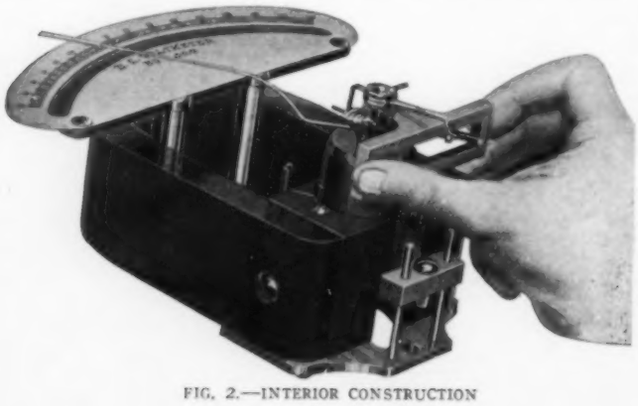


FIG. 2.—INTERIOR CONSTRUCTION

is suspended from the end of a fine wire or metal strip. Aside from supporting the moving element the suspension strip has another function, and that is to restore the moving coil or element to its zero position. It, therefore, has to be comparatively long and also small in cross-section. It is also necessary before using the instrument to carefully level it.

The advantages, however, to be gained from a properly designed and constructed voltmeter of high resistance are very marked and some of them are as follows: Any change in the length of leads connecting the thermocouple with the millivoltmeter from 1 to 1000 ft. will not change the indications of the instrument as much as 5°; nor will any change in the temperature of these leads introduce any error in the indications of the instrument; neither will the length of thermocouple, the size of the elements forming the thermocouple nor the length of the thermocouple inserted in the furnace change the indications of the instrument. All of these advantages are due entirely to the extremely high ratio of the resistance of the millivoltmeter in relation to the resistance of the thermocouple and leads.

The Brown Instrument Company, of Philadelphia, who have done so much in the past for pyrometry in this country, have for the past two years been conducting exhaustive tests to design an accurate, high-resistance, thermo-electric pyrometer. The result has been an instrument of the pivoted type; that is, a type in which the moving element or coil is not suspended from the end of wire or metal strip, but is absolutely supported by means of small hardened steel pivots in sapphire jewel bearings. The moving coil and pole pieces of the magnet have been so changed in design as to produce a magnetic flux of great intensity in the air gap in which the coil swings. This high-resistance instrument, having a resistance of 100 ohms, can be furnished in either the indicating type or the recording type.

In Fig. 1 is shown the standard type of indicating instrument of the high-resistance type made in the horizontal type so as to afford a long scale for easy reading. This type of instrument has a mirror under the scale so that absolute accuracy in readings can be secured.

In Fig. 2 is shown the interior construction of the high-resistance system showing the redesigned pole pieces and small moving element, the moving element having been lightened to a minimum.

The Brown Instrument Company has been able to design this system in such a manner that its cost is practically no greater than the cost of manufacturing the low-resistance instrument. The instrument can be used for either base metal or platinum thermocouples as desired and is recommended by the manufacturer for either type of couple. The same type of system is also used in connection with recording pyrometers.

Personal

Mr. **Max F. Abbé,** who has been engaged in the pulverizing and grinding machinery business for a great many years, is in Europe. The Abbé Engineering Company, 220 Broadway, New York City, manufacturers of pulverizing and grinding machinery, inform us that Mr. Max F. Abbé is their vice-president and is looking after their foreign interests in Europe.

Mr. **Maxwell W. Atwater** has been retained by the Ohio Copper Company to investigate the flotation process with a view to adopting it in the company's mill at Lark, Utah.

Mr. **Albert J. Bone** will be superintendent of the new smelting plant of the Granby company at Anyox, B. C.

Mr. **B. A. Bosqui** is to have charge of the new cyanide mill of the Commonwealth Mining Company, Pearce, Ariz. The mill will be ready for operation shortly.

Mr. **G. Montague Butler,** formerly assistant professor of geology and mineralogy at the Colorado School of Mines, has been appointed head of the department of geology in the newly organized Oregon School of Mines at Corvallis.

Mr. **A. H. Case,** formerly manager for the Tennessee Copper Company, Copperhill, Tenn., has accepted a position as consulting engineer for Lewisohn Brothers, New York City.

Mr. **John Dern,** who has been identified with several mining enterprises in Utah, has been offered an appointment in the diplomatic service under the present administration.

Mr. **George Flint,** Treasurer of the Radium Company of America, Sellersville, Pa., sailed on the S.S. "Caronia" for Europe. Mr. Flint's address is care London City & Midland Bank, London, England.

Messrs. **C. H. Fulton** and **J. Burns Read,** of the Case School of Applied Science, Cleveland, O., have been making a Western tour.

Mr. **Bancroft Gore** has been appointed professor of metallurgy in the Montana School of Mines, Butte, Mont. Mr. Gore was previously on the engineering staff of the Washoe reduction works of the Anaconda Copper Mining Company, and later smelter superintendent at the works of the Gatico Copper Mining Company, in Chile.

Mr. **Sidney J. Jennings,** vice-president of the United States Smelting, Refining & Mining Company, recently visited the company's properties in California.

Mr. **R. L. Lee** has been appointed assistant superintendent of the copper smelting works of the Central Chile Copper Company, Panulcillo, Chile.

Mr. **John L. Malm,** metallurgical engineer of Denver, has returned home from an extended business trip in the South and East.

The **Ray Consolidated Copper Company** announces the removal of its executive offices to 25 Broad Street, New York City.

Prof. **Heinrich Ries** is engaged by the Mines Branch of the Canada Department of Mines to make an investigation of the clays of western Canada.

Professor **Albert Sauveur,** of Harvard University, has been awarded the Elliott Cresson medal of the Franklin Institute, Philadelphia, in recognition of his work in metallography.

Mr. **George Schneider** has been appointed director of the mining section of the Colorado Industrial Exposition which is to be held in the Grand Central Palace, New York City, during the month of November, 1913.

Mr. **Frank E. Shepard,** of the Denver Engineering Works Company, has been to Ishpeming, Mich., to inspect the new iron concentrating mill of the American-Boston Company. Professor **Robert H. Richards** also visited the mill at the same time.

Mr. **Joseph T. Singewald, Jr.,** is making an investigation of the ores of the Silverton, Colo., district on behalf of U. S. Bureau of Mines. The results of the investigation are expected to be of assistance in devising suitable methods of ore treatment.

Professor **Alexander Smith,** head of the department of chemistry at Columbia University, has accepted a position as professor in Princeton University for the year 1914-1915.

Mr. **Bradley Stoughton,** secretary of the American Institte of Mining Engineers, was guest at a luncheon of the Colorado Section of the Institute on September 16. The local section was duly organized with the following officers: **W. J. Cox,** chairman; **C. J. Moore,** vice-chairman; **C. L. Colburn,** secretary-treasurer; **Richard A. Parker** and **Thomas B. Stearns,** members of the executive committee.

Mr. **L. A. Test** has resigned his position as assistant professor of chemistry in the School of Mines, Rolla, Mo.

Mr. **Pope Yeatman** has gone to Chile.

Mr. **Lewis E. Young,** who recently resigned the directorship of the Missouri School of Mines, will devote part of his time to teaching in the department of mining engineering, University of Illinois, and will also take up graduate work in the department of economics.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

REFINING METALS (*Continued*).

494,231, March 28, 1893, Charles B. Schoenmehl, of Waterbury, Conn., assignor of one-half to Alden M. Young, of same place.

Relates to refining metals using the same as secondary electrodes in a suitable electrolyte. For copper, an electrolyte of copper sulphate is used. The plates of crude metal are coated on one side with carbon or graphite, and the metal from the adjoining plate deposited upon the graphite coating. The patent refers to his copending application which became patent No. 494,232.

494,232, March 28, 1893, Charles B. Schoenmehl, of Waterbury, Conn., assignor of one-half to Alden M. Young, of same place.

Relates to apparatus for the refining of copper, etc. The crude metal is used as secondary electrodes. The vat contains supports for removable electrode holders, the holders serving also to maintain a uniform distance between all the plates, and also to support a diaphragm of a suitable fabric to protect the cathode side from floating impurities. The sides of the vat are perforated above the bottom, and communicate with parallel electrolyte vats, through which a constant circulation of electrolyte is maintained. The holes are so located as not to disturb any sediment at the bottom of the vat.

505,846, Oct. 3, 1893, Pierre DeP. Ricketts, of New York, N. Y.

Relates to a process of refining crude nickel, nickel alloys and other nickeliferous products. The product is first smelted or otherwise treated to reduce the nickel to the metallic state, and to remove most of the impurities. The metal thus obtained is rolled into suitable anodes and electrolyzed in an acid bath containing alkali salts, such as sulfuric acid containing sodium or ammonium sulfate, etc. During electrolysis the nickel forms a double sulfate with the alkali, which double sulfate is insoluble in the acid solution and precipitates to the bottom; it is subsequently collected and may be used for electroplating purposes, or it may be retorted; the nickel oxide thereby obtained is nearly pure and may be reduced by carbon. With nickel alloys as anodes, the remaining metal is either deposited during the electrolysis, as in the case of copper, or remains in solution, as in the case of iron.

514,275, Feb. 6, 1894, Lingan S. Randolph, of Baltimore, Md.

Relates to the refining of copper or other metals by electrolysis in a cell in which the crude metal sheets are disposed horizontally and electrolyzed as secondary electrodes, the current entering the cell through the bottom electrode and passing out at the top. The plates are suitably separated by glass, etc., the electrolyte is circulated so as to keep the slimes in suspension and carried out of the tank where they may separate and the solution be filtered before returning to the cell. The anodes are preferably rolled or pressed, but may be cast.

514,276, Feb. 6, 1894, Pierre deP. Ricketts, of New York, N. Y.

Refers to his prior application, which became patent 505,846, of which this is a division, and relates to the method of separating nickel contained in nickeliferous bodies from the other metals and impurities combined therewith, consisting in immersing and dissolving the nickeliferous bodies in suitable acids; in adding thereto sulphates of ammonia or other similar ammoniacal salts, so as to form and retain a bath having an acid reaction of such composition as to dissolve the copper and nickel and retain the former in solution and form with the latter insoluble salts; and in causing an electric current to traverse the bath continuously from a suitable positive terminal to a suitable cathode, placed therein, whereby the copper is deposited upon the cathode and the nickel salts are precipitated to the bottom of the bath; in collecting the precipitated salts and dissolving the same in water, separating the insoluble impurities contained therein; evaporating the solution to dryness and heating the residue in a retort, whereby the ammoniacal products are collected and condensed for further use, and the nickel residue refined in any convenient manner.

515,763, March 6, 1894, Carl von Grabowski, of Eisleben, Germany.

Relates to the purification of sulfate electrolytes or other solutions containing a plurality of metals and arsenic and an-

timony. A sulfuric acid solution containing metallic sulfates is evaporated until it reaches a specific gravity of 52 deg. Baumé, the copper and other sulfates being crystallized out. The resulting solution is electrolyzed with a current density of 60 to 80 amp per square meter of anode surface using anodes and cathodes of lead or copper. Arsenic and antimony are electrodeposited and the solution entirely freed thereof. If the concentration exceeds 52 deg. Baumé, arsenic and antimony sulfids will be electrodeposited, the sulfuric acid being decomposed with liberation of hydrogen sulfid.

532,209, Jan. 8, 1895, Bernard Moebius, of New York, N. Y.

Relates to a method and apparatus for refining metals, such as gold, silver, copper, bullion, etc. The apparatus consists of a horizontal tank in which is a traveling belt cathode preferably of thin metal, and above the cathode a series of removable trays having porous bottoms, the trays constituting anode compartments. The traveling cathode discharges its granular deposit upon a second traveling belt which removes it from the tank. The bullion to be separated is cast into anode plates and immersed in an electrolyte consisting of a strong solution of sodium or potassium nitrate sufficiently acidulated with nitric and sulfuric acid to keep some of the silver and all of the copper in solution. A current of small electromotive force is used, the silver being deposited upon the cathode in a loose, spongy state or in crystalline form. The copper is dissolved from the anode but remains in solution, while the gold and platinum metals are retained in the anode compartment, together with some lead peroxid, silver peroxid, and other impurities. Attention is directed to the improvement described in patent 592,097.

Book Reviews

Safety. By **Wm. H. Tolman,** Ph.D., and **L. B. Kendall.** Octavo (14 x 22 cm.), 422 pages, numerous illustrations; price 3.00 net. New York and London: Harper & Brothers.

This is an interesting and valuable book on methods for preventing occupational and other accidents and disease, the senior author being the Director of the American Museum of Safety. It discusses sources of danger and their removal in a dozen general types of works or factory, industrial hygiene in various occupations, and the social welfare of workmen in general. The information and advice are suitable and valuable to both employers and employees, while the general public will also find the book highly interesting and profitable reading.

* * *

General and Industrial Organic Chemistry. By Dr. **Ettore Molinari,** Professor at the Luigi Bocconi Commercial University, Milan. Translated by **Thomas H. Pope** of the University of Birmingham, England. Large octavo (15 x 25 cm.), 770 pages, 506 illustrations. Price, $6 net. Philadelphia: P. Blakiston's Son & Co.

Dr. Molinari wrote also a companion volume on Inorganic Chemistry, which has been reviewed in the January, 1913, issue of this journal (Vol. XI, p. 61). The two volumes supplement each other and really constitute one work.

After a short introduction on the properties of organic compounds in general the treatise is divided into two parts; derivatives of methane and cyclic compounds. The former embrace the saturated hydrocarbons, halogen derivatives, alcohols, derivatives of alcohols, acids, derivatives of acids and aldehydic alcohols; the latter all other organic compounds. Under each individual substance there is given its history, properties, preparation in the laboratory, industrial preparation and commercial value and uses. The commercial relations, price, imports, exports and consumption, are a particular feature, intended to give the reader or student the proper idea of the commercial importance of the material.

The information is in general commendably up to date; one exception is the antiquated calculations of the temperatures produced by the burning of various explosives, which need radical revision using modern values for specific heats of the gases produced. The calculated values given are impossible and make scientific calculations look ridiculous. The book, however, as a whole, is a most valuable and commendable work.

* * *

Iron and Steel. By **O. F. Hudson,** M.Sc., with a section on Corrosion by **Guy D. Bengough,** D.Sc. Octavo (14 x 22 cm.), 173 pages, 45 illustrations; price $2.00 net. New York: D. Van Nostrand Co.

This short treatise is one of the series of "Outlines of Industrial Chemistry," edited by Dr. Bengough, and is intended to present to engineers, users of metals and students of metallurgy the more important principles of the metallurgy of iron and steel. The seventeen chapters of five to fifteen pages each (average length ten pages) deal with mechanical testing, production of pig iron, properties of cast iron, foundry practice, malleablized cast iron, wrought iron, crucible steel, cement steel, Bessemer process open-hearth and electric steel, mechanical treatment of steel, impurities in steel, study of iron-carbon alloys, heat treatment of steel, special steels, steel castings, welding, corrosion.

Inspection shows the various chapters to be well and correctly written, and to contain as much information as could be expected in such small space. The work, however, gives only the merest outline of a very large field, making it suitable for beginners only or for those desiring only a general review of the present status of the subject.

* * *

Das Materialprüfungswesen. Edited by Prof. Dr. **F. W. Hinrichsen.** 25 x 16 cm. (10 x 6½ inches), 607 pages, 215 illustrations. Price, bound in paper, 18 marks. Stuttgart: Ferdinand Enke.

Dr. Hinrichsen, who is connected with the Institute of Technology of Charlottenburg and the Testing Bureau of Berlin-Lichterfelde, has had the co-operation of Dr. Martens and twelve of his assistants of the Berlin Testing Bureau, and of Dr. Maffia of the Dresden Testing Laboratory, in producing this review in condensed form of the whole field of testing materials mechanically, physically and chemically.

This is an immense field to cover and necessitated restricting the treatment to the best methods now in use in each case. The work is taken up in the following order: Metals and Alloys, Ores, Pigments, Building Materials, Paper, Ink, Textiles, Fuels, Water, Fats and Oils, Rubber, Leather, Explosives, and each chapter or part of a chapter is handled by a specialist—in most cases by the best specialist in that line in Europe.

Under these circumstances the work is exceptionally valuable and accurate, and well worth getting by anyone interested in the general subject or in any one of the various materials discussed.

* * *

The D'Este Steam Engineers' Manual. With electrical appendix by **Charles Penrose,** E. E. Second Edition. 117+356 pages, with numerous illustrations. Price $2 net. Boston, Mass.: Julian D'Este Company.

This manual which here appears in its second edition has been very considerably enlarged by the addition of an electrical appendix, prepared by Mr. Penrose. The steam section comprises 117 pages, the electrical appendix not less than 356 pages.

The book does not compete with specifically electric handbooks, but retains its character as a steam engineering handbook. In the electrical appendix the endeavor is therefore to emphasize those features of the *practical* side of electrical engineering which are of particular interest and importance to the steam engineer who has to do with electrical apparatus. The endeavor of Mr. Penrose not to shoot over the heads of his readers is very evident and we believe that practical steam engineers will find the book very useful. The old friends of the first edition should certainly become even better friends of the second edition.